Science, Old and New

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to

THE VERY REVEREND SIR GEORGE ADAM SMITH

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PRINCIPAL OF THE UNIVERSITY OF ABERDEEN

In Grateful Recognition

of

Never Failing Encouragement

PREFACE

THE science of Biology has naturally changed not a little since Darwin's day. To appreciate the changes one may utilize a systematic treatise of recent date, and this is what every serious student must eventually do. But there is another method, which this book illustrates, that of selecting a number of arresting topics and discussing these in the light of recent advances. This is a more indirect method of gaining some understanding of the New Biology, but it is not less fruitful.

Another motive underlies the studies here presented, that of continuing the disclosure of the unending interest of Animate Nature, even in everyday sights. One's ambition, not, alas, one's accomplishment, is expressed in Meredith's line: "You, of any well that springs, may unfold the heaven of things." The book is full of fresh facts—mostly the discoveries of others; but not less important is the presentation of these in a framework of personal reflections, some of which are fresh ideas in Biology.

Studies I–XX have mainly to do with problems of Natural History or Ecology; Studies XXI–XXXIX are more strictly biological; Studies XL–XLV discuss evolution questions; Studies XLVI–LII deal with man and his outlook.

It is a pleasure to thank the proprietors and editors of *The New Statesman*, *The Glasgow Herald*, *John o'London's*

Weekly, *Time and Tide*, and the *Illustrated London News* for their courteous willingness that I should use, as a basis for these studies, various articles of mine which have appeared in their columns.

J. ARTHUR THOMSON.

University of Aberdeen,
March, 1924.

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I

SCIENTIFIC SNAPSHOTS

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The Young Earth

As far as the eye could reach, a monotonous smoking desert, cindery under foot. Here and there out of a crack a sluggish crawl of molten rock, like very coarse-grained tar, hardening and blistering on the surface as it cools, and creeping out from beneath its crust in an ugly way. No sun by day, nor moon by night, nor any stars, but a thick curtain of cloud over everything. And beneath the cloud a heavy unbreathable air of carbonic acid gas and water vapour, much nitrogen, but only a trace of oxygen. There is no sign of life, nor any sound save crackling and hissing, and now and then a bomb. This was the surface of the cooling Earth—the future home of life—about 861 million years ago.

The Dawn of Life

A universal ocean, without continents or islands, but teeming with microscopic creatures swithering between plants and animals, more in a cubic foot of water than we can see of stars on a clear night. They move by living lashes; they trap the sunlight that struggles through the clouds; they feed on sea-water that is almost fresh and on the air that is mixed with it. Some of them grow and multiply by day, and die at night, for they have very

slender resources. These were the first living creatures perhaps 500 million years ago.

Ages pass; the floor of the sea has buckled here and buckled there; continents are formed with great deeps between. In the inshore waters, shallow enough to be well lighted, some of the primeval forms of life anchor themselves, and grow out into long threads and broad plates—the first sea-weeds. But from among these emerges a new kind of life, minute predatory creatures that feed on the plants and on their fragments. They steal the plants' munitions and explode them. These were the first animals, emerging, perhaps 400 million years ago.

The First Birds

A strange creature sprinting along the arid ground. It is a long-legged biped, about the height of a redshank, very spare and lightly built. It is like a bird in its sharply marked-off head, its supple neck, and its springy legs; it is like a lizard in its scales, its teeth, and its tail. As it runs it flaps its forelimbs, which bear a slight web and what look very like scales partly shredded up. After it gets some way on, it takes a long running leap, skimming over the ground. Occasionally, when a big reptile makes a clumsy feint at it, the startled creature leaps with a sharp cry on to a low-growing tree and disappears among the branches. This was the first bird—perhaps fifty million years ago.

Life in the Great Abysses

Vast undulating plains on the floor of the Deep Sea, like sand-dunes, but covered with slimy mud, treacherous to walk on. No scenery, no sound, no vegetation, not even rottenness. But many animals have colonised these

inhospitable deeps, some anchored, others slowly swimming, as if half asleep, and others walking delicately with stilt-like legs on the ooze. Sluggish existences devouring one another in a grim sequence of reincarnations, but the last link of the chain depending on the ceaseless snow of moribund minutiæ sinking through the miles of water from the surface overhead.

There is enormous pressure, many tons on every square inch of the body, but it is not felt. The current of life flows slowly and centenarians flourish. There is no light, save the fitful gleams of luminescence from fixed animals that sparkle like Christmas-trees, and from free-swimmers gliding slowly past like illuminated miniature barges. Otherwise utter darkness. Also intense cold, near the freezing point, due to the down-sinking of icy water from the Poles. What an eerie world, covering 100 million square miles, more than half of the Earth's whole surface, a world of eternal night and eternal winter, soundless, stagnant, and monotonous, a plantless world with a stern struggle for existence! Such is the Deep Sea, with its insurgent animal life.

The Bridge of Balgownie

Before it becomes an estuary on a small scale the river has cut out a gorge, where the water flows sullenly. Just at the Bridge, where it turns sharply and meets the tide, there is a deep pool—thirty-five feet deep, the neighbours say. A sinister corner it often seems, with its steep sides so easy to slip down, so difficult to climb up, with strange whirlpool movements in the turbid water as if some huge creature was coiling and uncoiling itself down below, and with ugly flotsam drifting round and round on the oily surface. *But the living is never ugly.* The banks, with their trees and shrubs, make a

beautiful frame all the year round, and there are wild cherry trees, breaking into living foam in the Springtime. And one day, as we looked down from the bridge, we saw, darting up-stream, what looked like an arrow made of a bit of rainbow. It was a Kingfisher at the Old Bridge of Balgownie.

The Courtship of the Blackcock

On a shoulder of the hill a walled sheepfold, and beside it a level sward of short grass, surrounded by small alders and birches. In the half-darkness we hid in the sheepfold and arranged a peep-hole through the wall. At the welcome dawn two Blackcock arrive, and begin to strut about, calling loudly. As the sun touches them they are transfigured. The vermilion wattles above their eyes shine out vividly. Their dark feathers show a changing play of blues and greens, and below the lyrate tail there is occasionally seen, like a flashlight, a great dazzle of silver. With hoarse cries the rivals rush at one another, jumping into the air, striking with beak and wings, raising the tail, scraping on the ground with their pinions. As the light grows, more jousters arrive, and the tournament becomes very lively.

By and by their desired mates, the Grey Hens, arrive on the scene, settling down quietly on the branches of the alder-trees. Their appearance strikes a new note; the tournament changes into a dance. Several cock-a-whoop males step on the stage at once, calling, jumping, fluttering their wings, and showing off till they are weary of their passion. It is a wonderful spectacle—the sunrise, the growing light on the hills, the green sward, the transfigured birds, the bluffing and fighting, the dance and the display. Echoing the excitement, we raised our head above the wall to see more of the Mysteries. There was a sudden clapping of wings and a gust in the alder-

trees, and the stage was empty in Glen Brora. Love's Labour Lost that morning!

The Ways of Stoats

On the putting-green in front of us we saw a circle of larks and meadow-pipits, standing quite still, as if spell-bound. And so they were, for in the middle of the circle there were two stoats at play. They were gambolling madly, somersaulting, and making incredible living wheels of themselves. The birds stood around, pre-occupied and amazed. Had we been able to make ourselves invisible, there would soon have been two larks amissing, for there is a method in the stoat's madness.

In front of us, in the fairway of the links, we saw a stoat going very slowly, which in itself was puzzling, for they usually lope over the ground at a great pace. We had to hurry on; we cried "Fore"; we could not but overtake the leisurely stoat. And then the puzzle solved itself. For it was a mother-stoat, taking her youngster for its first walk—a youngster so tender that it could not run. Just as we were upon them, the mother seized the young one by the nape of the neck, ran swiftly forward, laid it carefully in a bunker, and then came to meet us!

II

MAMMALS AND BIRDS OF THE MOUNTAINS

MAMMALS AND BIRDS OF THE MOUNTAINS

EVERY typical mountain shows three zones—first the forest and woodland, then the treeless steppe tracts with varied herbage and often with good pasture on shelves and plateaux, and then uppermost the relatively barren heights with "alpines" and lichens, like the tundra of the low moorland and plain. So if we try to take a survey of the tenants of the mountains, we can profitably distinguish those of the forest, such as bears; those of the steppe tracts, such as wild sheep and goats; and those of the sparsely clad uppermost stretches, such as the marmots of the high Alps.

Relict Mountain Animals

But we would suggest, for North Temperate countries, another grouping which is not less instructive, and is, in a way, more interesting. We may divide the tenants of the mountains into the *relicts*, the *insurgent colonists* and the *refugees*. By the relicts we mean the survivors of the Arctic or glacial tundra fauna that once extended, on the low grounds, from the north far into Central Europe. When the climate became milder and the glaciers retreated, many of the northern animals left their bones in the south. It was too mild for them.

Others, like the reindeer, probably managed to trek northwards, but others went up the mountains. Those who followed the last alternative are our relicts. One of the best examples of this is the little snow vole, which rarely descends below 4,000 feet, and goes up to the very summits. It has a tough constitution, it burrows beneath the snow from one root to another, it stores for the time of bitterest scarcity. The snow vole was originally a tundra mammal, but it has conquered the great heights and found an area where it has no enemies. Similarly, the marmot was once a tenant of steppe-land; its bones are found in low-ground caves and as far south as Gratz; but now it is at home in very inhospitable places in the Alps. It burrows, it stores bedding and blankets at least, it is quick to sound the danger signal—whistling through its teeth—and it circumvents the winter by sinking into sleep. Or, again, there is the mountain hare or blue hare, first cousin of the common maukin, but a distinctively northern species. In glacial and inter-glacial times it came far south in the low grounds; when a milder climate set in, some migrated and others climbed. So on the mountains this relict holds its own to-day, safe in its elusive roving, in its ability to thrive on short commons (nibbling at lichens when hard pressed), in its quiescence during the day, and in its winter assumption of a white dress which conserves the precious animal heat and gives the creature a Gyges ring, on a snowy background at any rate. As a bird to cap the mountain hare we may take the ptarmigan, famous for its three moults in the year. It is a northern bird, but in the more southerly part of its range it is strictly confined to high altitudes. Even in Scotland it has disappeared from the southern countries. On the mountains of the Highlands this non-migratory relict keeps its foothold. It can subsist on berries and shoots; it has a heart suited to the strain of living at a high altitude (far stronger than that

of its cousin, the willow grouse of the Lowlands); it turns white in winter; and perhaps there is a touch of perfection in the way it moults its worn claws and finds fresh ones ready underneath.

Insurgent Colonists of the Mountains

The second contingent of mountain animals consists of insurgent colonists from the steppe-lands, which found it practicable to make a living at considerable altitudes, especially where there are shelves and plateaux with good soil. Just as the industrious Swiss migrate in the summer to their "alps," and feed an astonishing number of cattle on these high mountain shelves, so many animals have done. The chamois is nowadays a mountain-loving antelope, but it was probably, to begin with, a tenant of the Asiastic steppes. It is hardy; it is alert to sense danger and give the social signal by whistling or stamping; it has a thick coat and a woolly under-vest; its hoofs are well suited for gripping the rocks, the outer edges being higher than the sole. Everyone knows how it disappears up what seems to the amateur an unscaleable mountain-side, or hurls itself down a precipice and looks up blandly from below. If we understand the chamois as an insurgent colonist from the low grounds, we understand a score of others, from the goral of Indian altitudes to the so-called Rocky Mountain goat which ascends to the loftiest peaks. Bovine animals belong to the plains and steppes, but the grunting yak of Tibet ascends to 20,000 feet. This black ox, as agile as it is strong, extraordinarily shaggy and Spartan, seems to delight in enduring hardness. Valued for hide and flesh and milk, it adds to its virtues in being docile. It is an unspeakably enduring beast of burden—crossing glaciers, pushing through snow-drifts, and fording ice-

cold torrents. It is a creature of the plains that has mastered the mountain-steppes, and if we understand the yak we also understand the numerous kinds of wild sheep and wild goats—the unlucky ibex of the Alps and the fine markhor of the Himalayas. It is the law of life to look out for niches of opportunity, and these insurgent colonists have found not merely a niche, but a shelf. Doubtless there have been many who tried whose constitutions failed to stand the rigorous tests. We have also to remember the age-long conflict between carnivores and herbivores, and the continual tendency of the latter to retreat before the former. To the sheep and goats the discovery of the mountain-shelves meant not only pasturage but safety—safety for a while, till the forest carnivores followed them; and so we understand the snow leopard and the mountain puma.

Let us take two birds for a change. Many are familiar with our long-billed tree-creeper, which runs up the stem like a mouse, stopping at short intervals to probe insects out of the crevices of the bark. A relative of this interesting bird is the beautiful rock-creeper of the precipitous cliffs. It falls down the face in zig-zag lines, checks itself by spreading its beautifully coloured wings; it ascends in jerks, opening and closing like a big butterfly, and picking out small insects and spiders with its long curved bill. If we understand the rock-creeper's colonization we have the key to Alpine accentor and Alpine swift, to rock thrush and snow finch, and more besides. We referred a moment ago to insurgent carnivorous mammals like the snow leopard, and we should place the golden eagle on the same platform—as a colonist of the heights, following such creatures as the grouse and the hare. To some extent doubtless it is also a refugee, for it is a slowly multiplying bird, and a bit of a specialist in its diet. It lives dangerously and naturally seeks safe retreats.

The Refugees

The third set of mountain animals includes the refugees, hard-pressed creatures which have sought out an asylum—a way of escape from the too intense competition of the crowded low grounds. This is well illustrated by the coneys or hyraxes of Africa, Palestine and Syria. They are small animals, "a feeble folk"; they are not very quick and not very clever—wary rather than "wise"; they have little in the way of weapons or armour; and they do not burrow. What chance have these old-fashioned creatures, almost anachronisms? Some of them have saved themselves by becoming arboreal, and the others by ascending the mountains, even to 10,000 feet. They have thick coats that "keep out the cold," and their feet are well adapted for scrambling among the rocks. Another refugee is the desman of the Pyrenees, an extraordinary bundle of curiosities, that occurred long ago in Britain. It is about five inches long in body and as much again in tail; it has a very mobile proboscis like the beginning of a miniature elephant's trunk, which it twists round its food. It is said to be able to put it into its mouth. Now this creature belongs to the dwindling order of Insectivores—a primitive group of mammals—and it keeps agoing as a refugee on the heights. In fairness we must add that it has also become aquatic, like our own water shrew, and that it is likewise a burrower. If we understand the desman's story, we also understand the Alpine shrew, the Tibetan mole-shrew, and the Himalayan swimming shrew; all are refugees.

Writing at the age of sixty-two, Ruskin said that though he had spent much time beside torrents, he had never seen a water-ouzel alive! This was an extraordinary statement, for the beautiful bird is very widely distributed throughout Britain on quickly-flowing streams that ripple over stones. It is particularly fond of mountain streams

and may be seen or heard at a level of 5,000 feet. Now the point is that the water-ouzel is a near relative of the wrens which has become aquatic. It walks on the bed of the stream, gripping with its toes, and it also uses its wings in a sort of underwater flight. It feeds on small water animals, and makes a domed nest of grass and moss under a waterfall or in some such safe place. The male's wren-like song may be heard in mid-winter, sounding so cheerily from a stone on the mountain stream that we wonder if the word conqueror would not have been better than refugee.

Let us take a clearer case to end with—the North American mountain beaver. This is a primitive rodent, almost "a living fossil"—a short-tailed, blunt-snouted, chunky creature rather over a foot long, grey to black in colour. It is a timid, slow-going animal, with a cumbersome gait, so leisurely that a child can catch it. It is dull of sight and hearing, and it has no voice except a noise made by rasping the lower incisors sideways across the tips of those above. Everything is against the survival of this anachronism, and yet it holds fast. When we ask "how?" the answer comes: it is elusive, nocturnal, a burrower, a storer of varied vegetable food, a social creature, very sensitive to touch and keen of smell. But to our thinking, part of the answer would be left out if we did not add that it goes up the well-clad hill slopes to 6,000–8,000 feet. The mountain beaver is a successful refugee.

III

THE UNDERWORLD

THE UNDERWORLD

THERE seems to have been a persistent endeavour on the part of animals to get out of the water on to dry land. In various ways it has been to them age after age an El Dorado—to some a place of safety, to others a less crowded home, to some a freer air, to others more abundant food. Thus, after plants had prepared the way, the dry land was invaded by successive contingents of animals—such as earthworms, centipedes, and amphibians, each great invasion with far-reaching consequences.

Difficulties of Terrestrial Life

But after adventurous pioneers of various races of animals had reached the promised land, they discovered that it was not always flowing with milk and honey. In water they could move freely in any direction in three dimensions; on land they were restricted to one plane—the surface of the earth. In the sea they could lay their eggs almost anywhere in the universal cradle of the waters, unless the struggle for existence was terribly keen; on land they had to hide the eggs, or bury them. Often the only solution of the difficulty was for the mothers to carry the young ones about with them before birth or after birth, not parting with them till they were more or less able to fend for themselves. Thus we see many a spider carrying about her eggs, and by and by her young

ones, in a silken bag. The kangaroo puts its very helpless, prematurely born, young ones into an external pouch, and it is quaint afterwards to see them going out and coming in.

The essential point is simply this, that the conquest of the dry land involves risks of drought and frost and overcrowding; there are no currents to bring food near; the abundant oxygen is more difficult to capture. Therefore it became necessary for some of the colonists to trek once more; some became arboreal and others got into the air; some became cave-dwellers and others, which we wish now to study, burrowed beneath the ground.

The Worm Invasion

There is a strong probability that earthworms sprang from a fresh water stock, which in turn had been started by migrants from the sea. Many not very distant relatives of earthworms are to be found in fresh water, and there are several genuine earthworms, like Alma and Dero, which possess gills. It is likely then that migrants from fresh water became burrowers beneath the surface and had for a time a Golden Age—a world of their own and plenty of food. As ages passed, however, the centipedes followed the earthworms underground, perhaps in the Carboniferous Period, and these continue to be their inveterate enemies. Then came burrowing carnivorous beetles. There is also in Brazil a carnivorous Planarian worm which follows the earthworms into their retreats, and in many countries the carnivorous slug (Testacella) does the same. Ages afterwards there were moles. Thus the earthworms have become a much persecuted race—their Golden Age long since over. How do they survive at all? They have become nocturnal; they are exquisitely sensitive to vibrations; they can grow a new tail or even a new head if what they had is cleanly bitten off.

The Fitness of the Mole

What a compact bundle of adaptations is a mole! Its shape is suited for tunnelling, its snout for thrusting and probing, its short muscular neck for tossing up the loose earth. Its shovel-like hands are broadened out by an extra sickle bone, and the muscles of the pectoral girdle are those of an athlete. It literally swims beneath the ground, and can turn through 120 degrees in four strokes. Negatively, it has no projecting ear-trumpet, for that would be in the way; the rudimentary eye is well protected with hair, so that it is not scratched; there are arrangements for keeping the earth out of the nostrils and the mouth. The hair has no "set" so that it is not ruffled when the animal moves backwards, and it is very readily kept clean. The mole is an extraordinarily strong and active animal, with a big appetite and unsurpassed rapidity of digestion; it is no coincidence that its staple food consists of earthworms, which are very abundant. In winter it can burrow below the grip of the frost's fingers, and it also makes caches of decapitated earthworms to serve as a last resource. Has not the mole conquered the underground world?

A Survey of Subterranean Animals

Until we look into the matter we do not realize the number and variety of subterranean animals, living like sappers and miners out of sight. There is sometimes a literal truth in the phrase "the living earth." Not very much is yet known of the Protozoa of the soil, the amœbæ and infusorians that live in damp earth. They are sometimes of agricultural importance, for instance, by devouring large numbers of the bacteria which bring about decomposition or other useful chemical changes in the soil.

At a much higher level are a few subterranean Planarian

worms and numerous threadworms which pass the whole or part of their life underground. Many of these threadworms are notorious for their destruction of garden produce and field-crops, and they are the more formidable because of their capacity for surviving prolonged drought. They lie inert and even brittle, month after month, even year after year, showing no sign of being alive, and yet not dead, as is shown by their reawakening when the rains return and the soil is once more moist.

The general significance of subterranean life is clearly illustrated by the larvæ of various terrestrial insects. The adults are usually able to fly, but they lay their eggs in the safety and moisture of the ground, and the larvæ live there for months or even for years, feeding on the roots of plants, and accumulating energy for the adult reproductive period when feeding often counts for little. The tough larvæ of click-beetles, known as wireworms, do incalculable harm in devouring the underground parts of plants, and it is difficult to discover any counteractive. Leather-jackets are the subterranean maggots of the cranefly or daddy-long-legs, and it is a not uncommon sight to see the rather graceful insect struggling out of the pupa-case which the larva makes just at the surface of the soil.

A different rank must be given to a number of adult insects that have become subterranean, such as some ants and termites, which dislike the light of day, and little small-eyed Staphylinid beetles, which are found only in the burrows of moles and hamsters. A very interesting miner is the mole-cricket (Gryllotalpa), a clever burrower with enormously strong fore-legs very suggestive of those of the mole. The list of backboneless burrowers includes two blind centipedes and a blind millipede. There are also some snails and slugs which go deeply into the ground.

When we pass from backboneless to backboned animals, we find a temporary burrower in the African mudfish (Protopterus), which buries itself in the earth when the

pool dries up, keeping its mouth at the foot of a narrow pipe that goes up to the surface. It may spend more than half the year in a lethargic state, and it is sometimes safely transported to London inside its mud-nest, which is then dissolved away to liberate the fish.

Certain old-fashioned amphibians, the blind Cæcilians, have sought refuge underground, and have assumed an earthworm-like appearance without any trace of limbs. Unlike frogs and newts, which are quite naked, these Cæcilians have minute scales imbedded in their skin, and this is one of the archaic features linking them back to a remote scale-bearing ancestry. Another interesting point is that the *unhatched* young have gills—a shunting backwards of a feature which would appear later if the Cæcilians spent their youth in the water after the fashion of ordinary amphibians.

It is rather striking to take one of these Cæcilians and place beside it a burrowing limbless lizard (an Amphisbænid) and a burrowing snake (say Typhlops), three animals belonging to very different groups, one an amphibian and the other two reptiles. Yet they are extraordinarily like one another externally—they show an earthworm-like cylindrical body, no trace of limbs, and minute, hidden, or degenerate eyes. Moreover, the big ventral scales which ordinary snakes use in gripping the ground are replaced in burrowing snakes by small scales like those which cover the rest of the body. Such superficial resemblance between unrelated animals is called "convergence"; it means that different kinds of animals have come to be similarly adapted to similar conditions of life—in this case, burrowing underground.

A burrowing bird seems almost like a contradiction in terms, and yet, besides the sand-martins which make yard-long tunnels when they nest, besides the puffins and shearwaters and stock-doves that utilize the holes made by rabbits, there is a burrowing parrot (Stringops) in Australia

which has given up flight altogether. Associated with this strange new departure there is a loss of the keel on the breastbone—the keel to which the muscles of flight are in part attached in ordinary birds. It is strongly developed in birds of powerful flight; it is absent in the flightless running birds; and we find it difficult to answer the evolutionist's conundrum: Did the burrowing parrot lose its keel because it took to burrowing, or did it take to burrowing because it was losing its keel?

What strikes us first in regard to burrowing mammals is that the habit has been resorted to over and over again by different types. There is the so-called marsupial mole of Australia; there are insectivores, like the archaic golden mole of Africa, the Scalops of North America, and the common mole of Europe; there are rodents like the prairie dogs of North America, the viscachas of South America and the Spalax of Europe.

A second fact that stands out is that these diverse mammalian burrowers have a good deal in common—a cylindrical shape, short strong limbs, short soft fur, a short tail or none, an absence of projecting ear-trumpet, and small or degenerate eyes. In other words, the burrowing mammals show similar adaptations to similar conditions of life. To suppose that burrowing mammals lost their ear-trumpet or pinna as the direct consequence of burrowing—rubbing it off, as it were, in the course of many generations, would be to take a very rough and ready view of evolution. The size of the ear is a variable character, as we see among ourselves; the probability is that those burrowers who varied in the direction of small ear-trumpets, and then none, would get on better than those with prominent ear-trumpets—which would be likely to become scratched and sore. The small-eared variants would gradually become the type of the race. There is an important calculation made by Professor Punnett, that if in a population of animals there were 0.001 per cent.

of a new variety, and if that variety had even a five per cent. selection advantage over the original form, the latter would almost completely disappear in less than a hundred generations. Apart from the risk involved in ear-trumpets that they would tend to become sore, and apart from the fact that big flaps would be in the way when it is important to reduce friction, it should be noticed that the use of the ear-trumpet is to collect the waves of sound in the air and aid in their localization, and that this purpose could not be served underground. We see the donkey moving his long ear without moving his head; we move our head without moving our ear; therefore our ear-trumpet is small compared with the donkey's.

The Ant-Lion

Animals have sought out many inventions, and one of the most original is to the credit of the larva of the ant-lion. The adult is an elusive flying insect, distantly related to dragonflies; the larva is a burrower of sorts. In sandy places it moves round and round backwards and excavates a funnel-shaped pitfall about the size of an ordinary watch and about an inch deep. At the foot of this widely open shallow funnel the ant-lion larva hides itself with the sharp tips of its jaws slightly projecting. Inquisitive ants come to explore the pitfall; they lose their footing on the treacherous slope; they tumble down and are seized by the ant-lion, who sucks the sparse juices of their body. Not less striking is the shaft sunk by the female Trapdoor spider as a safe hiding-place for her eggs and young.

We see, then, that in a great variety of ways diverse animals of low and high degree have sought refuge underneath the ground, sometimes in the interest of self-preservation and sometimes in the interest of race-continuance. Of the strange company, with this in common that they

inhabit the underworld, Mr. Edmund Blunden gives us a glimpse in his incomparable fashion:

I am the god of things that burrow and creep,
Slow-worms and glow-worms, mould-warps working late,
Emmets and lizards, hollow-haunting toads,
Adders and effets, ground-wasps ravenous;
After his kind the weasel does me homage,
And even surly badger and brown fox
Are faithful in a thousand things to me.

IV

A VISIT TO A BIRD-HILL

A VISIT TO A BIRD-HILL

ONE of the difficulties in telling of great sights—such as a bird-hill with its million birds—is the incredibility of the truth. Even in restrained approximations the cold-blooded listener hears the twang of the long bow. That must be felt by every visitor to one of the Scottish bird-hills, Handa Island; what one sees is incommunicable, and between the two timidities of telling the incredible truth and making a ridiculous under-statement, one is inclined to say nothing at all. But let us take our courage in both hands!

Handa lies about a mile off Scourie, and Scourie is almost the end of the world—how very far from the end of comfort and kindness those who stay there will soon discover. It is true that Scourie, which lies on the west coast of Sutherland, is relatively inaccessible, for it is about forty-five miles from the nearest station (Lairg on the east), but it makes up for this and a certain lack of restraint in its meteorological conditions by being near Handa, and by being encompassed by great mountains.

To get to Handa one offers libations to Neptune and gifts to Æolus, selects the finest day in the year (July 7th, 1922), makes friends with two skilful mariners, and sets sail, not unprepared for the swell on a sea which is open water to Greenland, and for a "jabble" of water where Loch Scourie opens into the Sound. On the voyage, which may last an hour, one sees plenty of birds on the water.

There are furtive green-eyed cormorants which look as if they had a guilty conscience, darting their bill nervously in all directions; unabashed puffins, with their moultable bill like a coat of many colours, which allow us to come quite close and then fly along the surface with much spluttering; and confident guillemots which dive through a roller and look at us from the other side. We asked the skipper quite politely to try to keep the boat along the hollows, but he paid no heed to our suggestion.

The Hill Itself

Handa is built of stratified conglomerate and sandstone, of Torridonian age, in great contrast to the tangle of older Archæan or Lewisian gneisses and schists on the mainland, which come, we believe, very near the original crust of the earth, and are almost terribly weathered down. Everywhere there are glacial striæ and smoothed hummocks; almost everywhere there is gaunt nakedness except in the troughs between the ridges where a shallow soil has accumulated or a peat-bog has been formed. We do not suppose the appearance of things has changed much since the last Ice Age.

Handa has a long grassy slope towards the mainland and precipitous cliffs to the north and west. To the north it looks—from a long distance—on Greenland, to the west on the Butt of Lewis and the hills of Harris. The island feeds about three hundred sheep and many rabbits. There used to be a few houses, but now there is only a shelter for the shepherd who comes over for six weeks at lambing time. There is a cache of oatmeal and tea for travellers who are marooned on the island by mist or storm. Like the widow's store, it is never exhausted.

We saw nothing remarkable on the long grassy slope—numerous "chacking" wheatears with brilliantly white rump feathers, besides insistent whinchats, plenty of

larks and heather linties or twites. Here and there a circle of small feathers on the short grass told of a hawk, and perhaps it was a crow that accounted for that freshly picked rabbit's skeleton. There were the characteristic flowering plants—butterwort and milkwort, bog-myrtle and sundew, marshwort and scented orchis. At the top of the bird-cliffs the sea-pink grew in great tussocks of root-work sometimes raised a foot off the richly manured ground. There was no heather out (July 7th) and the distant hills showed snow in some of their northward corries.

The Shelves of Birds

We were lucky enough to have as our guide the village schoolmaster—would it be wresting words to call him the *genius loci?*—who showed no little art in leading us always from the great to the greater on a crescendo plan. We came suddenly on a precipitous sea-cliff a hundred and fifty feet high, built up like a giant's book-case of successive sandstone shelves, from a foot to a foot and a half in breadth, and on these shelves there were tens of thousands of birds, often packed so closely that their bodies were touching and their necks crossing. In most cases the various kinds were quite separate, living, as it were, in different streets of Clifton. A common succession was this—lowest down, a kittiwake area; then a guillemot or razor-bill section with perhaps thirty shelves one above the other, and then at the top, where the turf began, the burrows of puffins. In some cases there would be a section of rock-face with guillemots only; in other places there were more razor-bills, easily distinguished from their cousins by compression of the bill from side to side; here and there a kittiwake had established a claim to an isolated broad bracket of rock and sat there on its nest surrounded by thousands of guillemots. We went higher

and higher, along the top of the escarpment, till the face of the cliff for three hundred yards or more was four hundred feet high, but everywhere the scene was essentially the same—long terraces of kittiwakes, guillemots, razor-bills, and puffins. In some places the guillemots and razor-bills were able to stand upright with their immaculate white breasts turned seawards, but most had their back outwards and pressed their body against the rock. The long webbed feet must be of use in gripping a downward sloping shelf, but the advent of an extra guest from the sea often overtaxed the capacity of a crowded corner and considerable dislodgment and altercation ensued. We saw many fights and heard much wrangling and murmuring, but the general impression was quite the other way. It looked as if there was much give and take, and though the noise was sometimes deafening, it sounded more like good-humoured gossip than quarrelling. One got an impression of general well-being, and the suggestion of repletion made one think of the multitude of fishes that must be needed every day to keep up the aplomb of the colony. Sometimes, we do not know why, the clamour changed its character and sounded querulous, a little like the tuning up of a hundred thousand bagpipes. The atmosphere reminded us of Emerson's remark about the average man that he had too much guano in his composition.

Birds and Man

To our presence the birds seemed quite indifferent, doubtless because of a well-established tradition of security. Shooting and collecting are nowadays rare at Handa. In a re-entrant angle between two cliff-faces there is a lofty isolated stack with a grass-covered flat top, which used to be moving with puffins. There are none now except along the edge, and the explanation

offered is this. Some years ago a party of fishermen-collectors came over from the Lewis and slung a strong rope across the re-entrant angle and right over the top of the isolated stack. It makes one's flesh creep to hear that they crossed by the rope hand-over-hand to the top of the stack, where they made things easier by fastening the rope to three poles, two of which are still standing. For sound economic reasons they cleared off the puffins in bags—there is a yarn about using trousers—and the level summit of the stack has been untenanted ever since. It got a bad name; it remains taboo to the generations of puffins.

The Life of the Birds

With a field-glass it was easy to watch individual birds, to see the preening, the caressing, the bickering, and to distinguish the young birds from their parents. Almost all the youngsters were ready to fly away, and we were lucky in not arriving the day after the fair. Some evening soon the crowds will become restless; the migratory impulse will begin to work; and in a short time the streets of the city will be desolate as far as guillemots, razor-bills, and puffins are concerned. Most of them spend the winter in the open sea and off the coasts of southern lands. The cormorants that we saw on broad shelves at the foot of the cliff, a few feet above the water, are practically residents in Britain, and so are the kittiwakes and other gulls. But the essence of the great sight is that the shelves of the cliffs afford a convenient and secure summer breeding-place, especially for the three members of the auk family—the guillemot, the razor-bill, and the puffin.

We say secure, because the birds have almost no enemies. The sea-eagle or erne is now extremely rare; the buzzards which still frequent Scourie can hardly venture

among the legions of sharp-billed guillemots; and it is improbable that the rapacious Great Black-Backed Gull, who was much in evidence, gets more than the weaklings. It is probable that some young birds tumble off the shelves, or are killed in the course of their education, but one gets the impression that in spite of the abundance of life there is not much death. One must remember also how Darwin showed that the top-like shape of the single egg of the guillemot or the razor-bill allows of rotation without rolling, should it be jostled by the wind or by the parent's feet.

Having shown us the 400 feet cliff-face with perhaps 400,000 birds, our guide was wise enough not to let us down gradually. He took us to a gigantic, unsunned, dark-walled Devil's Pot-hole, perhaps 250 feet deep, with the sea rolling in by two openings at the foot, and there we saw *no birds at all.* All along the escarpment it seemed that the birds avoided dark and damp places. There were other untenanted sections which seemed to us suitable enough, but some, at least, of these showed evidence of the dislodgment of great slices from the rock's face. This would give the section a bad reputation.

Having greatly enjoyed our impressions of the abundance, the gregariousness, the adaptability, the resourcefulness, and the victoriousness of life, we climbed to the grassy summit of the island and saw on the mainland the amphitheatre of great mountains—one of the most magnificent views in Britain—from Sulven, Canisp and Quinaig in the south to Ben More of Assynt, and from the massive cone of Ben Stack, past Arkle, Fionne Bheinn (2,980 feet), and Spionnaidh to Grianan, beyond which lies Cape Wrath. We eventually remembered the patient boatmen down below, who rowed us back—wind and tide against them—to a hospitable roof, but very late for dinner.

V

A NATURALIST'S PARADISE

A NATURALIST'S PARADISE

THERE is an island in the heart of the Everglades of Florida which bears the attractive name of Paradise Key, and the account of it given by Mr. W. E. Safford in the Report of the Smithsonian Institution for 1917 warms the naturalist's heart. It is a sub-tropical jungle within the limits of the United States. The primeval conditions of animal and plant life have remained unchanged by man, for the clearings and fires and drainage which have greatly altered many of the Everglade Keys have left this one untouched. Apart from certain insects and poisonous plants, every prospect pleases; and the collector finds a closed door, for Paradise Key is now a State Park and a three-mile-square sanctuary for living creatures, plants as well as animals.

The Everglades of Southern Florida represent a recently raised area of the sea-floor, and consist in great part of marshes and sloughs and shallow ponds, with lime-stone rock cropping up here and there, giving a foundation for trees. During the rainy season of the warmer part of the year the Everglades are flooded; in the dry winter months they can be crossed on foot. Along one border of Paradise Key there is a deep slough which never dries up, and this gives a particular stability to the bionomic conditions and greatly lessens the risk of fire.

Exuberant Vegetation

From Mr. Safford's report we get, first of all, an impression of the abundance of vegetative life. There is a mingling of temperate persistence and tropical exuberance. The deep slough is crowded with water plants, yellow water lilies, water arums, whose leaves and roots, like those of the British cuckoo-pint or jack-in-the-pulpit, are crammed with needle-like crystals "which burn the mouth like fire," pickerel weed or Pontederia with spikes of blue flowers, besides Sagittarias, "floating hearts," bladder-worts with traps for small crustaceans, and many kinds of aquatic grasses and sedges. The "saw-sedge" is one of the guardians of the Everglades, its margins and keel thickset with very fine and very sharp teeth. Out of the water are the marsh-loving plants, the amphibious willows, the swamp bay smelling of bayrum, the wax myrtle from which candles can be made, the white-flowered magnolias with silver lined leaves, besides mangroves with their stilt-like roots and small groves of cypress. On the more solid ground are trees—the magnificent live oak of the Southern States, "which sometimes spreads its moss-covered branches over an area 200 feet in diameter"; the gumbolimbo, which exudes fragrant balsam when it is wounded; the golden-brown satin leaf; the laurel-cherry, with leaves rich in prussic acid; the wild tamarind with fern-like foliage; the wild olive, and the pigeon-plum. Even the names transport us into a land of pure delight—the paradise tree, the myrtle-of-the-river, the marlberry, and the bois-fidèle (incorrectly translated "fiddle wood"). Another note is struck, however, by the great poison-tree, a giant sumach, the sap of which acts like the poison ivy of some American woods, or like the milky juice of another sumach that furnishes the almost indestructible, but poisonous, Japanese lacquer.

But we were almost forgetting the palms (some over 100 feet high) and palmettos, and the Caribbean pines. Most remarkable of all is the living fossil called Zamia, a descendant of the giant cycads of the Carboniferous age. The pollen from the male plant, borne by the wind, settles on the naked ovules of the female plant, and sends out a pollen tube. In this, as in other Cycads, there are produced relatively large motile spermatozoa like those of animals and of non-flowering plants such as ferns. "The ovules of *Zamia floridana* develop into beautiful orange-red fleshy fruits arranged about a central axis, like large grains of corn around a cob. These are at first covered by the peltate, triangular scales which bear them, but they fall off when fully ripe and form conspicuous bright-coloured heaps in the pine lands where they grow"—interesting jetsam of a vegetative tide that spent itself long since.

The Struggle for Life

From the impression of the abundance of plant life rises another, the impression of struggle. There is keen competition, seen in miniature in our hedgerows, for light and fresh air. The

"jointed liana" roots in the ground, forming loops which trip up the unwary; "its opposite, arm-like branchlets, which terminate in tendrils, clasp the tree trunks as the plant makes its way up to the light. When it has established itself, and spread over the branches, the arms, no longer of use, break off at the shoulders and leave the vine hanging like a great rope usually at some distance from the trunk, causing the observer to wonder by what means it had reached its point of support. This plant covers the crown of a tree so thickly that its host is sometimes crushed under its weight."

There are many others—vines, zarzaparillas, a cassia bearing nicker nuts, a giant bean, and the sweet bamboo

briar, all illustrating in various ways the same endeavour. Strangest, perhaps, is the strangling fig, *Ficus aurea*, which starts, like the mistletoe, from a tiny seed dropped by a bird on the limb of a tree. It sends down threads which reach the ground and root. "They grow together wherever they touch one another, forming a meshwork about the trunk of the host which is slowly strangled to death. This may well be designated the snake tree, or constrictor, of the vegetable world." It is interesting to notice that the extreme competition of the jointed liana and the strangling fig is apt to defeat itself by killing the supporting host. Mr. Safford's fine pictures recall Stevenson's *Woodman:*

> Thick round me in the teeming mud
> Brier and fern strove to the blood:
> The hooked liana in his gin
> Noosed his reluctant neighbour in:
> There the green murderer throve and spread,
> Upon his smothering victims fed,
> And wantoned on his climbing coil.

It may seem that we were premature in saying "every prospect pleases," but perhaps if there had not been this sort of woodland warfare in the cycad forests of the Carboniferous age, there might not have been any flowers upon the earth to-day.

Linkage of Lives

It is pleasanter to think of the orchids on the trees, the highwater mark of the floral tide, such as the white-flowered spider orchid which exhales exquisite fragrance towards nightfall, and the chintz-flowered orchid which Hans Sloane compared in 1707 to patches of Dutch chintz, and a common one with yellowish-green flowers which blooms continuously throughout the greater part

of the year. There are many other epiphytes, some of which hang down in beautiful moss-like festoons. The "resurrection fern," growing on the branches, shows an interesting adaptation, for it curls up its fronds in drought and uncurls them when the rains return. The bromeliads, also perched on the trees, have at the bases of their leaves little reservoirs in which water collects, making a sort of arboreal swamp in which tree-frogs and even dragonflies lay their eggs. This is our third impression, the endless intricacy of the interrelations by which one creature is linked to another in the web of life.

The abundance of water-plants in the slough allows of a vast population of small water animals, crustaceans, insect larvæ, molluscs, and all the rest; and these afford food for higher incarnations in fishes, reptiles, and birds. "One of the most common occurrences is to see a magnificent osprey swoop down on what appears a grassy prairie and rise with a good-sized fish in its talons." Similarly, the great marsh snail is the staple food of the Everglade kite, and the crawfishes support the blue heron and the white ibis. The welter of humbler creatures makes a higher grade life possible, and the animate world is run on a plan of successive incarnations. This, again, is an impression of linkages.

Abundance of Animal Life

The wealth of insect-life is baffling—butterflies like the unpalatable zebra-marked Heliconius which insectivorous birds leave unmolested, day-flying wasp-moths with transparent windows in their dainty wings, lustrous jewel-wasps which lay their eggs in the decanter-like earthen nests of the potter-wasps, leaf-cutting bees, carpenter ants, a lichen-like mantis with bad habits, and, delightful to watch, graceful dragonflies, "like squadrons of miniature airplanes, waging incessant war upon the

besieging mosquitoes." Very curious are the opalescent ground-pearls found in quantities in the black soil of the wood. Children string them into necklaces. They are the exudations of certain scale-insects or Coccidæ, and the creature may be found inside. Many insects mean many spiders, some of which make us dumb by their diablerie. The female Golden Miranda, nearly an inch long, makes a web about two feet in diameter among the marsh grass; the male is only a quarter of an inch long and requires to be very circumspect. Another paradise spider is *Nephila clavipes*, whose golden-yellow silk, woven into bed curtains, was exhibited as a curio at the Paris Exhibition. She has an insignificant bridegroom whose honeymoon often comes to a premature end. The young ones are cannibalistic from birth. Our fourth impression from Paradise Key is of the still unfathomed subtlety of animal behaviour.

Higher Animals

There are many fishes in the adjacent waters, from tiny top minnows, which devour the larvæ of mosquitoes, to the big bony pike or alligator gar (up to seven feet), famous for its voracity and for its beautiful armour of enamelled rhomboid scales. There is another very interesting fish of ancient pedigree, another living fossil, the well-known Amia, "one of the hardest fighters that ever took the hook." Amia is famous for gameness and voracity; but look at the other side, turning from hunger to love—"the male builds the nest and guards it after the eggs are laid; he is a good father, even accompanying and protecting the schools of young after they leave the nest." Why should it be thought that this aspect of the struggle for existence is any less a matter of fact than the cannibalism of the spiderlings?

Passing reluctantly over the tree-toads (one of them

"scarcely bigger than a dime"), the Floridan bull-frog which grunts like a pig, the turtles and terrapins, the alligator and the crocodile (both of them timid creatures, very much afraid of man), the so-called chameleon famous for its quick changes, and a variety of friendly and unfriendly snakes, we reach the climax of the whole—the birds and the mammals. The latter include the Floridan opossum, various rats and mice, a lynx, an otter, a raccoon, and various others; while in the waters not far off there is the manatee, called a sea-cow by some and a mermaid by others (so much depends on the point of view!), one of the two representatives of the old-fashioned order of Sirenia. The birds are far more numerous and more fascinating—the Everglade kite, the osprey, the uncanny snake-bird which dives from the trees after fishes, the American bittern, stately "lady of the waters," the black-crowned and yellow-crowned night-herons ("whose day begins after sunset"), the white ibis and the roseate spoonbill, one of the most beautiful of birds, delightfully social in its ways. This masterpiece of gracefulness and fine colouring has become very rare in North America, doomed by the very beauty of its plumage. It is to be hoped that it will be saved from extermination in the sanctuary of Paradise Key, for it is the climax of our final impression, that of the Ascent of Life. We were so much charmed by Mr. Safford's report that we have ventured to try to hand on these five impressions which are dominant in our mind, but we know that they cannot have the convincingness of the original detailed picture. Yet we do not need to visit the Floridan Everglades to verify these fundamentals—the abundance of life, the struggle for existence, the intricacy of vital linkages, the subtlety of animal behaviour, and the general ascent of organic evolution.

VI

SEA SNAKES AND SEA SERPENTS

SEA SNAKES AND SEA SERPENTS

ONCE upon a time, millions of years ago, there were genuine sea serpents; and we are not denying that there may be some living to-day. But people who talk about them are looked queerly at, so let us keep to the facts as long as we can. We are alluding to the Pythonomorphs that lived in the Cretaceous seas. As the greatest living palæontologist in Britain says—"They must have had a very wide distribution, remains being met with in Europe, North and South America, and New Zealand." They belonged to the Lizard-Snake alliance, but they were sea serpents; and they flourished at a time when modern lizards and snakes had not been evolved. One must remember that in these distant Cretaceous days the ruling class was still reptilian; the future ruling classes, the birds and the mammals, were still at the level of "cranks." We fancy, however, that these incipient creatures, of higher cerebral degree, gave the dominant reptiles a good deal of anxiety. We are attracted by the suggestion that the "death-feigning" or "playing 'possum'" of various mammals may have historical reference to the time when the only chance of the pigmy incipient mammals in the clutch of the overwhelmingly big reptiles was to lie low, and pretend to be dead. For, while we cannot be sure about the extinct Dinosaurs, we know that many modern reptiles insist on catching living booty for themselves.

Extinct "Sea Serpents"

The Pythonomorphs differed from true snakes in having paddle-like limbs, but they were like true snakes in the elongated body (up to 45 feet), the large number of vertebræ (up to 130), the loose union of the two halves of the lower jaw in front—an adaptation which allows of swallowing relatively large victims. Towards the same end there is a remarkable hinge half-way along the lower jaw on each side, which must have allowed a bowing out in a curve when the booty was "too big for the mouth." The backward curving of the teeth is plainly suited for fish-catching. One of the best known of the Pythonomorphs is Mosasaurus, called after the Meuse near which its fossil remains were first found. Perhaps we are wrong in applying the name "sea serpent" to these Pythonomorphs or Mosasaurus, for we do not dare to say much more than that they belonged to the lizard-snake stock. We must not make too much of the elongated eel-like shape, for it is said to have arisen 44 different times in the evolution of Vertebrates. The Pythonomorphs left the land early in the Cretaceous; they were terrors of the sea for perhaps 3,000,000 years; and then towards the end of the geological middle ages (Mesozoic) they suddenly disappeared.

Modern Sea Snakes

Now let us turn to the modern sea snakes (Hydrophidæ), a very interesting family, widely represented from the Persian Gulf to Australia. There are a lot of them; sometimes seen a hundred miles from land, very poisonous fish-eaters. Like the Pythonomorphs they have sprung from a terrestrial ancestry, and they show some intelligible adaptations to marine life. Thus the tail is flattened from side to side, making a better paddle; and the same is sometimes true of the posterior body. It may be ex-

plained that the tail of a snake is usually short; it is the region behind the end of the food-canal and its vertebræ have no ribs. The single lung of the sea snake is very long, reaching right to the end of the food-canal, and this must make it easier to remain a long time under water; for it must be kept in mind that the inspiration and expiration must take place at the surface.

An ordinary terrestrial snake has along its ventral surface a single row of large scales, which grip the roughnesses of the ground. These are replaced by small scales in the sea snakes, except in one case, the gentle but poisonous Platurus, which keeps to the ancestral type and often ventures ashore. An ordinary terrestrial snake is continually feeling its way and testing things with its mobile sensitive tongue; it is interesting to find that in the sea snakes the tongue is very short. These differences as to scales and tongue are intelligible when we think of the aquatic life, but it is not so easy to understand why the sea snakes have small eyes, or why they moult the outer covering of the skin in rags and tatters, instead of in a continuous slough as ordinary snakes do. Perhaps a peeling off *en bloc* would be difficult in the open water; perhaps it would leave the animal imperilled.

The sea snakes are elusive and irascible reptiles. They are as awkward on land as they are agile in the sea, and when they are captured they lash about wildly, biting even at their own body. They seem to be half-blinded by the glare. Their bite is very dangerous, and may be rapidly fatal to man. A naturalist writes of an experience in Manila Bay:

We were anchored about three miles from the land, in water twenty feet deep. To while away the time we fished, but either our tackle was too clumsy or our bait unsuitable, for we had not even a bite all day. As night came on we kept our lines in the water merely for experiment's sake, without the remotest idea of catching anything. The sea was calm,

and the darkness intense. Between 9 and 10 P.M. we caught six water snakes on hooks of large size, baited with salt pork, and resting quietly on the bottom. They were of about the same size, three feet long, and very savage, snapping at everything within their range.

One is not surprised to find that the sea snakes are viviparous, for the developing eggs would soon drown in the sea, and apart from bringing forth living young ones the only other practicable possibility is that the mothers should bury their eggs on the warm sandy shore as turtles do, or should lay them on land and brood over them. But true sea snakes, except the aberrant Platurus, never leave the water, though in some cases the mothers bring forth their young ones among the sea-shore rocks and guard them there for weeks. The case of Platurus reminds us of the important conclusion of Dr. G. A. Boulenger, that besides the true sea snakes or Hydrophidæ there are three other marine groups which have diverged independently from terrestrial ancestors. Why creatures so thoroughly terrestrial as snakes should take to the water at all is a difficult question. Perhaps there was over-crowding, perhaps there was over-persecution, perhaps the land became too arid even for snakes, perhaps there was gradual subsidence of the coast, perhaps the spirit of adventure moved certain types to explore a new kingdom. It is often good science to say "perhaps."

Sea Serpents

But we wish, thirdly, to say a little about the sea serpents of modern times, of many of which careful descriptions have been given. No one can doubt that many sober witnesses have seen the *appearance* of sea serpents. To what are these appearances due? We may, as it were, distinguish several species of sea serpent, and some are better species than others! There is an Indian file of

porpoises; a chain of sea-fowl flying low; an immense length of kelp slowly drifting; a couple of 30-feet long basking sharks keeping time as they swim, one behind the other; an immense jellyfish with its frilled lips trailing behind for over 30 feet; the silvery oar-fish, 20 feet long, lurching in some agony out of the water; a pair of huge sea-lions or elephant-seals playing in the waves; or some huge cuttlefish, which with its long arms may reach a length of 60 feet. These are some of the species of sea serpents, but there are two considerations which lead us to refrain from dogmatically interpreting every sea serpent as a misinterpretation! First, there are several careful descriptions which cannot be readily referred to any of the species we have just noticed. Second, it must be remembered that sailors have good sight and are very familiar with many of the appearances noticed above. They declare that the sea serpent *they* saw was none of these! Surely it is too soon to suppose that we have discovered all the creatures of the sea. We are not aware, for instance, that anyone has seen the cuttlefish to which there belonged the scale-covered chunk exhibited by the late Prince of Monaco at the Paris Exhibition.

VII

THE ENCHANTED WOOD

THE ENCHANTED WOOD

REMEMBERING what Wordsworth has said as to the educative value of a vernal wood, we recently visited a summer wood—by the shore of Windermere. Perhaps it is the season that makes the difference, but we have not found any fulfilment of the poet's promise of increased wisdom. Or it may be that the fault is ours, or the wood's? For there is great diversity in the character of woods, as everyone knows. The pine forest is stern, like an army before battle; the beech wood is kindly, with squirrels scampering about, and the rustle of the thick carpet of strewn leaves is pleasant under foot; the birch copse in the Scottish Highlands is full of delicate fancies, and at every turn a right of way to fairyland. But the wood we tried to make friends with, and could not, was another kind of wood, a sheltered wood, a Circean wood. It is like a garden enclosed, screened from the winds that prune, with a hothouse mildness, with an almost tropical luxuriance. We have called it Circean, partly because of the abundance of Enchanter's Nightshade (Circæa), and partly because we were glad to be out of it—symbolic as it seemed of the sheltered life of ease.

Seen from a distance—we wish to be quite fair—the wood is very beautiful. It slopes up the hillside like terraces of thatched cottages, a pleasantly uneven and variegated verdure. It is what one calls a mixed, self-

sown wood, with oak and elm, hazel and alder, sycamore and ash, rowan and wild cherry—but hardly a decent tree amongst them. It is not that they are young; what is wrong is that they have not grown up. Tall, lanky weaklings, struggling up to the light, without girth, without grit. Some of them have become the dead or dying props of ivy. In other cases we saw sapling and honeysuckle sharing a common doom. Seedlings everywhere, delicate beauties without strength, crowding one another, shadowing one another, dwarfing one another. It is like the jungle in Stevenson's Woodman. Beauty, of course, and an absence of disease, apart from parasitic moulds and rusts, gall flies and leaf mites, but what a lack of vigour! So many of the leaves are ætiolated, which does not mean withered; so many of the stems are smothered in lichen. Not only are there mosses spreading up the branches, but polypody ferns as well, perched high above the ground. Everything speaks of the struggle for air and light; almost everything confesses failure. It is a depressing enchanted wood.

The undergrowth is dense; there is no brown earth to be seen. But the dominant impression is of much, not of many. The poverty of the flora is extraordinary, in the sense that only a few different kinds are represented. Only those have survived that are able to endure the deep shade. There were stretches of blaeberry bushes without any flower or fruit, ramping brambles that never have more than blossoms, and prostrate honeysuckle and ivy that seem to remain quite vegetative. Here and there a mass of woodruff without any fragrance, a bed of dog's mercury, a clump of wood sanicle with beautiful glossy leaves, clusters of wood sorrel, and everywhere enchanter's nightshade; but that is almost all. In other words, there is a sparse flora of shade plants—beautiful, no doubt, and luxuriant, but within a very narrow range. Quarter of a mile away, the meadow is a blaze of colour even in late

August—purple centauries, ruby-coloured salad burnet, golden rods, horse gowans, sage, agrimony, and a dozen more, but in this enchanted wood there is hardly a touch of any colour but green. Very characteristic are little glades of graceful cow-wheat with pale yellow pendent blossoms, sometimes almost white, but we could not find even common weeds like wound-wort or herb-Robert—no, not even a thistle. There was not a single flower that could be called a flame; nothing got beyond smouldering. There was no mistaking the inhibition of the sheltered life. We were in a crowd of beautiful invalids, and even the leaves were often dwarfish.

The tangled green curtains shut out the sun and the breeze; the rain drops from the forenoon's shower still hung from the leaf tips; the atmosphere was like that of a hot-house; and if we had been told that the percentage of oxygen was under the average we should not have been surprised. At first we rather liked the dense shade and the absolute quiet—without even a hint of the procession of char-à-bancs not very far away—but it gradually became sinister. It was like being in a cave. There were exquisitely beautiful old silver lichen cups and mosses with spore cases of gold, and no doubt there was an abundant cryptozoic life of microscopic animals, but beyond pin-point midges and an occasional slug on the uppermost branch of a thorn, there was no indication of the delightful creatures that usually "glide in rushes and rubble of woody wreck." How one would have welcomed a toad or even a brisk centipede! We did not expect an orchestra of birds at the end of August, but we only heard one in the wood—a churring fern owl, and, of course, with his garment of invisibility, he was not to be seen. Away in the distance we heard a barn owl and a moaning dove, but neither of them belonged to the enchanted wood. Here and there we saw that spiders had been at work, but it was part of the picture that what they had made were rough

and ready snares rather than true webs. What they had caught were winged green-flies or Aphides.

When we came to the far end of the wood there was a rustic bridge and the only joyous thing we had seen—a stream that made a silver staircase of broad low steps, stretching up and up through an endless pergola of green boughs. It was illumined to the outer side, and dark towards Circe's wood. We hurried across the bridge, glad to be away from the sheltered life of ease, back in an open and strenuous world where there is less luxuriance and more virility.

VIII

CAVE ANIMALS

CAVE ANIMALS

The most highly evolved tenants of caves are bats, and their choice of a dark home is congruent with their twilight activities. They do not like the light of day; they have made a speciality of the dusk. Some of the caves of the East are peopled by thousands of bats, and travellers tell us how kites and falcons congregate every evening outside a cliff-cave and await the *sortie.* In a brown torrent, ten feet deep and ten feet wide, the bats rush forth, and it is easy for the birds of prey to secure abundant booty. Yet the nightly thinning does not seem to make any appreciable difference in the number of the bats. They are legion.

Permanent and Partial Troglodytes

But in thinking of bats as cave-dwellers, we must remember that, weather permitting, they sally forth every night, just as otters may, or hedgehogs from the bole of the old tree. The bats are not like the permanent tenants which are found in moist or wet caves, such as the Mammoth Cave of Kentucky, or the Adelsberg Caves not far from Trieste. Let us take the Proteus of the Adelsberg Caves as a good example of a true troglodyte. This quaint creature is a newt about ten inches long, of a wan white colour, slightly tinted by the red blood which makes the three pairs of protruding gills a vivid carmine. The

eyes are degenerate and quite hidden below the skin, so it must be by smell or by detecting movements in the water that Proteus secures the small animals on which it feeds somewhat ascetically. The caves are quite dark; the water of the stream that traverses them for miles has a low temperature of about 10° C.; but Proteus seems to thrive. Experiments show that it is put about by the light of a candle, and we must regard it as an animal with a constitutional antipathy to illumination—some innate delicacy, perhaps, which has led it to seek out a dark asylum. Very remarkable, however, is the fact that experimental exposure to light results in the development of grey patches on the skin, and eventually in the appearance of dark pigment all over the body. It would have seemed so natural to conclude that the pigment-producing quality had quite dropped out of the inheritance of this cave-dweller, and yet experiment proves that it has not. Given the fit and proper nurture, the hereditary nature expresses itself; the white newt becomes black. We should be careful at a higher level not to conclude too hastily that dwellers in darkness have quite lost a quality, though they show as little of it as the Proteus in its caves shows of pigment. A near relative of Proteus, called Typhlomolge, occurs in subterranean caves in Texas—a fine instance of parallelism in evolution, for the two animals doubtless arose independently from an ancestor like the North American Necturus.

Is Cave-Blindness Due to Disuse?

We cannot do more than nibble at the familiar problem —did living in darkness make these cave-newts blind and wan, or did they seek out an asylum in darkness because of innate variations in the direction of weak eyes and weak pigmentation? Goldfishes kept in absolute darkness for three years become totally blind, losing the rods and cones

of the retina. There is no doubt as to the individual modifications—dints due to peculiarities of nurture; but we do not know, though we ought to know, whether the offspring of the blind goldfishes were the worse of what happened to their parents. When small freshwater crustaceans, such as "screws" (Gammarus), and "water-slaters" (Asellus), are kept for a long time in darkness they become very pale, and if the experiment is continued for years, generations are born with almost no pigment. But this may simply mean, as in the case of Proteus, that the stimulus required for pigment-production is absent during the development of the individuals. If translucent individuals are taken from the caves and kept in the light, they become brownish. One experimenter who exposed young stages of Proteus to the light, declares that the eyes advanced far beyond their usual state of arrested development. It is obviously very difficult to discriminate between peculiarities imprinted on individuals and peculiarities due to hereditary defect; and, likewise, to decide between the neo-Darwinian theory that ascribes the hereditary defect to a germinal weakness, and the neo-Lamarckian theory that ascribes the hereditary defect to the cumulative results of disuse and darkness. It is quite possible, moreover, that a hereditary defect may be exaggerated in the individual by the peculiarities of cave nurture. But this is a King Charles's head among biologists.

Very interesting is Professor Doflein's case of a tiny Japanese crab (Cyclodorippe) which occurs in two very different habitats—shallow water and deep water. In the shallow-water variety the eyes are well developed and darkly pigmented; in the deep-sea variety the eyes of the adult are very rudimentary, though those of the larvæ, which the mother carries about with her, show all the essential parts and are dark in colour. Here we have to deal with a seeing variety and an almost blind variety of

the same species. But it would be rash to conclude that it is all a question of habitat; there is probably a constitutional dichotomy that leads the two sets of variants to different haunts.

Another very instructive case is that of a blind and colourless fish, Typhlogobius, which lives on the Californian shore. This seems almost a contradiction in terms till we find that the fish keeps exclusively to dark places under shelves of rock—sea-caves in fact—where it fixes itself by means of its pelvic fins united into a sucker.

Caves as Asylums

Among the true cave-animals we include representatives of newts and salamanders, fishes, snails, spiders, insects, centipedes, crustaceans, worms and humbler creatures. They tend to be translucent or dull in colouring; they often show arrested or degenerate eyes, but by no means always; they have usually a fine sense of touch; and they seem to be able to thrive on very little food. It is a strange company, impoverished by being shut off from the sun's energy. More facts are necessary before we can give a secure interpretation of the origin of cavernicolous animals and of the peculiarities they exhibit, but we incline to the view that the majority are handicapped by some constitutional infirmity, such as inability to keep a place in the sun, and that they have found in the caves an asylum. They are not weak because they are troglodytes; they became troglodytes because they were weak.

IX

HERALDS OF SPRING

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For many millions of years there was no living voice to be heard on the earth. The only sounds were inanimate, like those of wind and wave, thunder and torrent. Unless we count the instrumental volubility of certain insects, like grasshoppers and crickets, which produce sound by moving one part of the body very quickly on another part, the first voice of life is to the credit of amphibians—probably towards the end of the Old Red Sandstone epoch. For amphibians were the first animals to have vocal cords—tightly stretched membranes which give forth sounds when the out-breathed air passes rapidly over them.

Croaking of Frogs

It is interesting that the first animals to have a voice should also be among the first animals to break the silence of winter. For frogs are among the earliest heralds of the Spring. There are, indeed, heralds of the Spring who cut a finer figure than do the frogs as they emerge from the mud by the side of the pond, or from secluded holes where they have spent the winter, but there are few that we can trust more confidently. When a lot of them have begun to croak we may be fairly certain that it will not again be very cold, that the winter is over and gone. There is many a snowstorm after the cawing of the rooks—false prophets of Spring—but there is rarely one after the

croaking of the frogs. All the winter through they have been lying half-alive, mouth shut, nose shut, eyes shut, breathing through their skin in a way higher animals have quite lost, and with their hearts beating feebly. Now they are awake again, and, in spite of their long fast, their slowly moving thoughts are all for love and none for hunger. The males call to their mates, who are weakly but distinctly responsive; the pairing instinct must be satisfied first, meals will come later. Love is stronger than hunger.

To our ears there is nothing very attractive in the frog's croaking, but it is not meant for our ears. It is a sex-call, and that is the primary significance of the voice.

Other Heralds

As we sat in the sun by the riverside we heard many heralds of the Spring. Handsome oyster-catchers with ruddy-orange bill and feet flew up and down in parties of three or four uttering shrill screams. They must cover scores and scores of miles in a day. The lapwings were flying very high and calling to one another, half plaintively, half mischievously. There was a voice also in the whirr of their wings as they swooped past us at top speed. There were redshanks with a beautiful trill in their clear whistle, and the curlews that had come to the river from the sea had a new music in their call. Little titmice were playing hide-and-seek among the branches of the larch-trees and calling to one another with sibilant incisiveness. There were jackdaws, too, in high spirits, besides thrushes and blackbirds, chaffinches and robin-redbreasts, and more besides—all calling, "Here I am, here; come hither love—here."

It seemed almost a bathos when some frogs gave voice from a marshy place close by the river, but one must hear with more than the hearing of the ear if one is to under-

stand aright. This croaking—why, it is a persistent echo of the first voice, and as such eloquent. If frogs had not croaked, could man have become man? Let us linger over the Natural History of the voice.

Drummer-fishes

As we have seen, a true voice began with backboned animals, and to all intents and purposes with amphibians, which made their appearance at the end of the Devonian Epoch. But fishes are not altogether mute. In the case of the drum-fishes there is a voluntary production of sound, most marked at the breeding season. The sound seems to be due, not to a grinding together of pharynx teeth, as was formerly supposed, but to a rapid and regular contraction of a special muscle on each side of the middle line of the ventral surface. The contractions and relaxations of this muscle rhythmically reduce and increase the size of the body-cavity, and there is a tendon running up to the swim-bladder which acts as a resonator, adding considerably to the carrying power of the sound. In some kinds of drummers there is drumming in both sexes, but there are other kinds in which it is the male's prerogative. In both sets of cases the drumming is probably a love-signal.

The Amphibian Voice

Among amphibians, in the frogs and toads there is the first true voice. That is to say, the air from the lungs passes rapidly between two taut membranes (vocal cords) which vibrate and produce sounds. In the Surinam toad the vocal cords are represented by two rods of gristle, which also vibrate, reminding one of a tuning-fork.

It is part of the tactics of evolution to make an apparently novel thing out of what is really very old. "New lamps for old" is the ancient magician's cry. So the frog's lungs correspond to the swim-bladder or air-bladder of the fish and the parts of the gristly framework of the larynx correspond to gill-arches. What the vocal cords, stretched within the larynx, correspond to, we do not know. Perhaps they are distinct novelties. For while there is a conservatism in evolution, using the old for something new, there is also creativeness, originating new things of which we can give no more account than we can of genius. "God said: Let Newton be, and there was light." The first Amphibian to give voice was another genius. The carrying power of the sound is often increased by the development of a resonator, the so-called croaking sac. The deep bass call of the American Bull Frog is said to be audible at a distance of a mile—measured on the spot. The croaking sac is an expansion of the floor or sides of the mouth, single and median, or paired and lateral. In many male frogs the croaking sacs can be protruded like big soap-bubbles from the corners of the mouth. In the tree-frog the inflated resonator may be larger than the head. The croaking-sacs are restricted to the males, and, as regards the voice itself, the females are either dumb or weakly responsive.

The noise that male frogs can make is familiar to those who live near marshes. It was likened by Aristophanes to "brek-a-brek-brek-brex-kaka-brex," and it must be granted a distinct specificity—each amphibian has its own particular love-call, its own and no other's. There is great diversity—croaking, quacking, trilling, ringing, chirping, howling, and caterwauling. Batrachologists can tell different kinds of frogs and toads by the voice. Its efficacy in summoning the females is well known. In newts and salamanders, unlike frogs and toads, there is little or no voice.

The Reptilian Voice

Reptiles, though higher than amphibians, are less vocal. Some of them have vocal cords that vibrate when the outbreathed air passes rapidly over them. In crocodiles there do not seem to be any vocal cords, but a sound is made by the air passing through the narrowed glottis (the opening to the windpipe), and below this there lies a resonating sac. Some crocodiles bury the eggs deeply in sand and mould, and when the young ones are ready to be hatched they pipe from within the egg. When the mother hears them she unearths them, otherwise they might be buried alive. This is an interesting case because it shows us the broadening of the use of the voice; it has become a child's cry.

Some lizards chirp; the monitors hiss; chameleons hiss and grunt. Perhaps these are deterrent sounds—another use of the voice. This is probably the meaning of the serpent's single fearsome word. The rattle at the end of the rattlesnake's trail, rapidly vibrated when the animal is excited, is an instrument made of a series of hollow horny tail-sheaths which remain attached at a sloughing. It is rattled with such rapidity that a whistling sound results, and this may be useful in driving off large animals, like peccaries, on which the snake might have to waste its poison. For the rattlesnake has no hiss.

The same kind of instrumental voice is illustrated by the males of most terrapins, which produce a clear note by rubbing a patch of tubercles on one leg against a similar patch on the other leg. Some of the climbing lizards or geckos produce similar musical notes, in both sexes, by friction between the scaly rings on the tail. But a true reptilian voice may be heard when the male tortoise wakes up at the breeding season; and some may have had the good fortune to hear the hoarse bellow of the male giant-tortoises of the Galápagos Islands.

The Voice Comes to Its Own

In birds and mammals the voice comes to its own, and in both we have to do with vocal cords the tension of which can be altered. But there is this great difference: that the seat of the voice in mammals is in the larynx at the top of the windpipe, whereas in birds it is in a new structure, the song-box or syrinx, situated at the base of the windpipe, where it divides into two bronchial tubes going to the lungs. Matters have become much more complicated, thus in a singing-bird there is the bony framework of the song-box, the internal vibrating membranes and folds, and a number of special muscles—up to seven pairs of them. The apparatus is usually simpler in the females, for singing is the cock-bird's art. In various birds, like the ducks, and in various mammals, like the howling monkeys, the vocal apparatus is enhanced by the addition of a powerful resonator.

But the most important fact of all is that while the voice remains in birds and mammals an expression and a provocation of love, its use has greatly broadened. It may be a parental call, a danger-signal, a filial cry, an appeal to kin, a means of conveying information, an instrument of social integration, and—eventually—a medium for expressing or concealing thoughts!

X

A SOCIETY SECRET

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AMONG ants, bees, and wasps there is often vicarious parenthood. The "workers" who take solicitous care of the young are not themselves normally mothers; they are females who remain, except in unusual cases, virgin and sterile. But as they are incomparable nurses, it has been generally supposed that they act as they do because of an engrained maternal instinct established in the history of their race long before there was any worker caste. In this view there is probably more than a grain of truth, though it should be remembered that the workers among Termites or White Ants are of both sexes. But the widely accepted view would obviously be easier to hold if we knew of any immediate reason—apart from that of racial welfare—why the parental care exhibited by the non-reproductive workers should continue so strong. That reason seems now to have been discovered.

The first hint of the reason was disclosed by Dr. Roubaud, whose studies of some tropical wasps showed that there is an interesting give and take between the nurse-wasps and the larvæ. The nurses feed the larvæ unremittingly, yet not without immediate reward, for they get from the larvæ drops of an elixir of which they are extraordinarily fond. The vibrations of the nurse's wings serve as the signal which prompts the larva to protrude its head for food, offering in exchange the delectable drop. A corroboration of this reason for the workers' devotion is

given by Prof. W. M. Wheeler, who shows that a similar kind of "symbiosis" holds for some kinds of ants, and probably lies at the roots of the social habit.

Danger of Biologism

But before we summarise Prof. Wheeler's story, we would suggest a caution, that the discovery of a physiological factor does not disprove, what is so difficult to prove, the reality of a psychological factor. In their constant routine of feeding, licking, transporting and defending the young, the worker-ants exhibit extraordinary persistence, and it is a tenable position that the expression of the inborn ready-made capacity which we call instinctive, is suffused with awareness and backed by endeavour. In many cases of instinctive behaviour this assumption seems almost necessary if we are not to make the whole business magical. But the via media is difficult. On the one hand we have grown away from the old view that everything is cleared up by invoking "the compelling power of affection"; on the other hand we feel that a physiological urge is a poor substitute for mind. It was only part of the truth that Swammerdam stated in the *Biblia Naturæ* (1737)—"with incredible affection" (he used the Greek word "Storge") "and care the ants bring up their vermicules and omit not the least thing appertaining to their education and nurture"; but it was a glimpse of a truth without which, as it seems to us, all is darkness.

The Larva's Give and Take

The mistake has been made of taking for granted that the sluggish legless larva or grub is only a passive recipient of the food the workers supply. In many cases it is far otherwise. Prof. Wheeler finds that in some of the Ponerine ants the workers turn the larvæ on to their broad

backs with their head and neck folded over on to the concave ventral surface, "which serves as a table or trough on which the food is placed." This food usually consists of fragments of insects which the workers have dismembered, and on these the grub discharges from its salivary glands an abundant digestive juice. This dissolves the food on the table, so that the grub can swallow and assimilate it, but—and here is the point—it also supplies a pleasant draught for the nurse. It is well known that the common tropical tailor-ants use the young larvæ of the nest to supply from their silk glands the silk threads with which they weave a web among the leaves; what is now made clear is that the large salivary glands of many other ant-larvæ supply refreshment and food to their nurses. In some larvæ that have soft blunt jaws and are fed with drops of regurgitated liquid food, there is no external secretion of salivary juice. But some of them have delicate tubercles or a tentacle-like outgrowth containing coagulated liquid which seems to be exuded and licked up by the workers when they are feeding and attending to their charges.

Exudations Extraordinary

The exudate, which is prepared in what is called the "fatty body" of the larva, is really blood rich in nutrient substances, and it probably filters through microscopic pores in the cuticle. That this is not unique we are reminded by the familiar experience of having a blister-beetle or a lady-bird discharge on our fingers, from particular points on its legs, a strongly smelling liquid, which turns out to be blood-serum. But an exudate that has a repulsive and offensive function in the blister-beetle may have an attractive or nutrient function in certain ant-grubs. And again we may recall what Father Wasmann and others have told us of the attractive exudation that

comes from the blood-fluid and the fatty body, or from special skin-glands, in some of the little beetles which various ants keep as guests or pets. The exudation is sometimes distributed on special hairs, and from these it is easily licked up by the ants, or is simply evaporated, much in the same way as the secretion of sweat-glands is diffused and evaporated from the hairs in man's armpit. There is a very interesting Tineid caterpillar, found in the tree nest of one of the Termites, which has seven long tapering appendages on each side of its body, from which there seems to be an evaporation of an exudate with a strong, probably alluring, odour. On Termites themselves, as well as on their guests, there is often a marked development of exudation, and the amount of licking that the workers go in for is probably, as Holmgren says, "not the immediate expression of an altruistic philoprogenitive instinct," but rather an "exudate hunger." Escherich reports that the workers in a Ceylonese termitary actually tear tiny strips off their bloated queen's cuticle in order to get at the attractive exudate more readily.

Weird Domestic Economy

What Roubaud discovered in some primitive African wasps was a weird domestic economy. The larval secretion is enjoyed not only by the adult females who bring food, but by males and by newly-hatched females, who give the larvæ nothing. But they know how to turn on the tap by vibrating their wings and touching the grub's lips. Roubaud suggested that the retention of the young females in the nest and the co-operative rearing of a large number of larvæ, crop after crop, may be traced back to the nutritive (or trophic) exploitation of the young. Social life, he said, is founded on "œcotrophobiosis." But as this term does not bring out the fact that in the main

the feeding of adults and larvæ is *reciprocal,* Professor Wheeler suggests the term "trophallaxis" (Greek "trophe," nourishment, and "allattein," to exchange). The nutritive relationship is clearly and characteristically co-operative or mutualistic.

Nutritive Exchanges

The thesis then is, that the social habit among certain ants and wasps is based on a nutritive exchange between adults and larvæ. That the symbiosis now exists is certain; that it is the outcome of an evolutionary process is suggested by an inclined plane of intermediate stages between merely storing food for the young and directly feeding the young, between feeding them right away and first preparing the food, between taking a share in the meal and finding the saliva of the larva agreeable, and so on. In attributing so fundamental a rôle to nutritive exchange, Professor Wheeler sees the difficulty that the social honey-bees and humble-bees show no trace of it. For there does not seem to be any evidence that adult worker-bees ever feed on larval secretions. But this may be because social bees have evolved along vegetarian lines, living on nectar and pollen which are abundant and easily obtained. Another objection may be found in the fact that the ant-grubs turn into ant-pupæ (the "ants' eggs" of the shops), and while these yield neither liquid exudates nor secretions, they are carried about and defended by the workers just as carefully as were the larvæ. It appears, however, that the pupæ have an attractive odour, and it is possible that their nurses have reminiscences! Moreover, pupæ as well as larvæ

represent so much potential or stored nutriment available for the adult ants when the food-supply in the environment of the colony runs very low or ceases entirely. Infanticide

and cannibalism then set in, with the result that the devouring of the young of all stages may keep the adult personnel of the colony alive till the trophic conditions of the environment improve.

Other Nutritive Linkages

Professor Wheeler's theory opens up an expanding vista of great interest. A linkage that is, to begin with, a mutual relation between the mother-insect and her brood "has expanded with the growth of the colony like an ever-widening vortex." The adult members of the colony may feed one another with regurgitated food or even with secretions; other species may be roped in to be fed and licked, alien races like the green-flies may be herded and "milked" (Linnæus's *vaccæ formicarum*): and so the web of interrelations is woven—a web which becomes the subtle sieve of progressive new departures in socialisation. Another very interesting point is that the guests or pets kept by ants and termites often exhibit very remarkable and even bizarre shapes, suggestive of man's fantails and bull-dogs. The probable explanation of this is that when sociality forms a biological unit larger than the individual or the family, and surviving in virtue of its qualities as a whole, there is permissible along certain lines (with restriction along others) a considerable latitude of individual variation. Another line of interesting inquiry concerns the rewards of altruism. Even the exacting ante-natal partnership between the mammalian mother and her young, is normally one of health, of give and take, of symbiosis. For it has been shown that hormones or regulative chemical messengers pass not only from the mother to the unborn offspring, but from the offspring to the mother. And is there not in the characteristically mammalian giving of milk a feeling of pleasure physiologically grounded—a pleasure which, as Bonnet suggested in his *Contemplation de la Nature* (1764) does something to

sustain the natural affection of the mother? And might one not work onwards to the fact that in his social inter-relations man finds one of his most rewarding methods of realising his self. Goethe said that Nature was always taking advantage of her children's capacity for self-forgetfulness; but do we not, even in this story of trophallaxis, get a glimpse of a deeper truth, that the activities which last best are those which bring with them some immediate reward.

XI

ANTS AND PLANTS

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It is well known that some ants collect seeds, like those of broom and gorse, and that they nibble at them, especially at the "oil bodies." They often lose their booty on their homeward journey, and, as they often use human tracks as their roads, this may account for the frequency with which bushes of broom and gorse grow by the sides of narrow footpaths on the moor. There is no doubt as to the seed-collecting, though it is not always certain what the ants make of what they gather. This seems to be the case, for instance, with the seeds of the cow-wheat, which are so like "ants' eggs," or, to be correct ants' cocoons.

Agricultural Ants

The habit of collecting seeds points the way to storing, which is a subject by itself; it may also be the beginning of agriculture. But the old story of the agricultural ants of Texas, investigated by McCook, Lincecum, and others, is not beyond criticism. There is truth in it, but the interpretations of the earlier observers were a little too generous. Round about their nest the agricultural ants make a clearing, often ten feet in diameter, and occasionally as much again. They are said to level the ground, and to leave patches of the grass Aristida, the seeds of which they collect and store and eat. Radiating from the clearing there are roads, which extend into the rank herbage, and

are used by the ants continually on their food-collecting expeditions. Moreover, according to the old accounts, the ants are in the habit of sowing the ant-rice in the clearing and keeping the patches of their crop free from weeds. But Professor W. M. Wheeler has found nests of this agricultural ant without any Aristida grass in the vicinity; and, as to cases where dense patches grow near the nest, it is said that these are due to the ants' habit of dumping down those Aristida seeds which have begun to sprout prematurely in the underground nest. It is a pity to spoil a good story, but the moral is that what looks like a well-thought-out scheme may not be so clever as it appears!

Ants' Flower Gardens

One has read of "hanging gardens," and they are to be seen as the handiwork of several kinds of ants in the region of the Amazons. They are made of earth, well kneaded and salivated, and they are attached to the branches of various trees and shrubs. Often they are the size of a man's head, and they may be built fifteen feet from the ground or over fifty. The interior is a labyrinth of passages, where the busy workers run up and down. Sometimes there are underground dwellings as well. But where does the flower garden come in?

The earthen nests are perhaps, just vast artificial extensions of the cavities of the plant in which the ants found their primary shelters when they took to arboreal life, but they have become something more, for, along with the building materials, there are included the seeds of many different kinds of flowering plants. These sprout and grow and blossom, and thus arises a flower garden. Naturally enough, the cultivated plants are for the most part local "epiphytes," or "perched plants," adapted for life on trees; but they have the advantage of being rooted

in the earth of the nest. Sometimes they grow so luxuriantly that they make the nest too damp for the ants, but usually they shelter the nest from the torrential rains. It cannot be said that the whole matter is clear, but the flower gardens are roomy dwellings for the little people, and they are raised above the reach of the great floods. There is no evidence that the ants get any food from their gardens.

Myrmecophily

Thomas Belt, who was one of the early observers of the leaf-cutter ants, was greatly impressed by their destructive powers. They defoliate certain trees persistently, and they must in this way sift the forest. But it was a great pleasure to the naturalist of Nicaragua to discover that the leaf-cutters did not have it all their own way. He found that there were other ants that lived on the trees without doing them harm, and that these drove away the devasting leaf-cutters. This was independently discovered by Delpino, and so arose the theory of myrmecophily, to which the botanist Schimper made very important contributions. By a "myrmecophilous" (ant-loving) plant is meant one that affords food or shelter or both to a bodyguard of ants, which in turn drive off predatory and altogether destructive assailants, such as the leaf-cutters.

Some of the acacia trees of tropical America have large thorns (due to the transformation of stipules) at the base of their beautiful compound pinnate leaves, and in these thorns the bodyguard ants find shelter. But they get food as well as lodging, for the tips of the leaflets bear minute oval or pear-shaped bodies (Belt's corpuscles), which are rich in protein and fat. They turn out to be transformed glands. They are easily detached, and they are much appreciated by the ants. When leaf-cutters

trespass on the preserves of the acacia ants, they get a hot reception, and are driven off. Thus myrmecophily "pays."

Another much-studied case is that of the Imbauba, or Cecropia-tree, of Southern Brazil; a tall, slender tree with palmate leaves. It is tenanted by Aztec ants, who find their way through pre-formed weak spots into the architectural cavities of the stem. Schimper said that, if the observer looks on quietly, he will see the Aztec ants running about looking after the aphides, or plant lice, whose honeydew they utilise, or nibbling at glandular white hairs, rich in protein and fat which grow at the base of the leaf-stalk. But if the observer knocks on the tree he rouses an army. Out of the little holes in the stem the members of the bodyguard stream in thousands, angrily excited. And this is the reception the leaf-cutters get. There is sometimes an Imbauba-tree without a bodyguard, but it is soon stripped by the leaf-cutters. Moreover, when Schimper found near Rio de Janeiro a kind of Cecropia without the pre-formed doorways (botanically interpretable), and without the palatable nutritive material and *therefore* without a bodyguard, and yet not defoliated, he discovered that this was an exception proving the rule, for a covering of slippery wax on the stem of this species made it difficult for the leaf-cutters to climb up.

Criticism of Myrmecophily

All this sounds very plausible, and it is almost against the grain to turn to modern criticism, such as may be found in Professor Neger's masterly *Biologie der Pflanzen*, to which we are much indebted. But it is urged, for instance, that the bodyguard is not nearly so necessary as has been asserted; that the acacias and Imbaubas are very prolific; that many ants that render no benefit are fond of the dark, dry cavities of plants that need no protection;

that the bodyguard cannot be always credited with either success or courage; that the ants inside the hollow stem of the Cecropia do harm by attracting the attention of destructive woodpeckers; that the food afforded by even a large Imbauba is not nearly enough to sustain the bodyguard. And this does not exhaust the criticism.

Yet account must be taken of the simple fact that the natives of Java have been in the habit for a long time of utilising a large red ant to defeat the incursions of a beetle that destroys the precious fruit of the mango-tree. They arrange bridges of rope, or the like, from tree to tree, so that the ants, which are inveterate enemies of the beetles, may move about freely. If this works well, as it seems to do, why should we be ultra-sceptical in regard to the protective value of the bodyguard ants? What seems to be unsatisfactory in the theory of myrmecophily is the exaggeration of the adaptations by which the plants are supposed to have answered back to their partners, and an inadequate appreciation of the alertness with which ants are always on the outlook for some new niche of opportunity.

That the ants have wrought out transmissible modifications on the plants which they frequent is exceedingly improbable; that the ants have turned the inborn peculiarities of certain plants to their own advantage, yet without serious damage to their hosts, is exceedingly probable. The story of myrmecodia is instructive. These are great swellings, sometimes two feet across, on the tubers of some plants related to coffee. They are riddled with passages and tenanted by crowds of ants; and they were interpreted by Beccari as direct responses on the part of the host-plants to the industry of the tenants. But Treub soon proved that the galleries are present, even when the ants are absent; and it is now generally admitted that the primary significance of the myrmecodia is as absorbing-organs for the plant.

The instances we have given of inter-relations between plants and ants are only samples, but they must suffice. There are many ants that grow fungi and the leaf-cutters prepare a culture bed for fungoid growths, by chewing their collected leaves into a green paste; and there are ants that interfere in a high-handed way with the remarkable triple alliance established between (A) a beetle, (B) a kind of cochineal insect, and (C) the leaf-stalk of a leguminous tree! We have said enough to illustrate the general tendency in animate nature to link one living creature to another in a complex web of life.

XII

INSIDE AN ANTS' NEST

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ONE of the uses of science is to make the opaque translucent. If we really know the anatomy of an animal we can see through it. In the case of a snail within its shell, for instance, we can see the heart beating in its proper place; we can see the liver and kidney in their proper places, both very active; and so with the other organs. Similarly, the anatomist can see right through the human body, and the botanist can see what is going on in the living parts of the stem of a tree. The embryologist who knows his business can, without looking, see what is going on inside the egg-shell on each of the twenty-one days of the chick's development. Our present desire for translucency is none of these; it is to see inside an ants' nest, as if its walls were made of glass. As in the case of "observatory-hives" for bees, so, by means of "formicaries" for ants, this close scrutiny has been made possible to ordinary people. For experts like Professor Forel, who has been scrutinising ants all his life in wild nature as well as in the laboratory, what goes on behind the curtain is quite clear. Can we form some impression of the things that happen inside the ants' nest, just as we might in regard to the processes that take place in a human factory? Let us, for a little, borrow Forel's spectacles.

Resting

In the open we see ants extraordinarily busy; they seem indefatigable; their industry is an obsession. No creature could live long at their rate, and we know that in summer the worker hive-bees are very short-lived—little more than a month. Among ants, however, there are resting periods within the nest. An individual worker comes in with a crop full of honey; the indoor attendants make it disgorge; and then it is packed off to bed. It is often very tired, unwilling to pull itself together even when a danger signal is "sounded," but after a rest it returns to its labours. That is one thing to be seen inside the ants' nest—*rest*. The less we say of "sleep" the better, for we do not know much about sleep among backboneless animals. What we are sure of is that the ants get tired, and that they sink into a sort of collapse from which they do not like to be roused. "Yet a little more slumber," they seem to say, "yet a little more folding of the antennæ." When danger forces them to get on to their feet they move sluggishly, as if half awake, and they do not rescue the cocoons as normal ants always do.

Silent Conversation

Another thing that goes on inside the ant hill is silent conversation. There is a sort of deaf-and-dumb alphabet, the instruments of which are the feelers or antennæ. These mobile and richly innervated structures, which are also the smelling organs, are used in passing the time of day. One ant strokes another's antenna, and the other ant answers back. So it goes on alternately. We do not know what they talk about, but we think it must be about old times: "You remember that feast of honey." Sometimes an ant will strike another hard with its jaws when it is breaking some rule or remaining careless in face of danger. But that is a different kind of talk.

Care of the Young

Much of the internal life of the nest is concerned with the young. The workers sometimes help the queen in her egg-laying, licking and massaging her. They carry away the laid eggs and deposit them in a suitable place, licking them repeatedly. Sometimes they are so fond of the eggs that they eat them; and when workers lay eggs, as they sometimes do, they have been known to eat them on the spot. The unnatural is apt to occur when the evolution of a large societary form perturbs the ordinary instincts of the individual, for we must face the fact that the success of the ant-community depends on a semi-repression of the workers. We do not think that Socialists would refer so often to the success of ants if they knew a little more about the seamy side.

When the larvæ are hatched out of the eggs they have to be fed, and the workers disgorge honey or chewed food into their mouths. The larvæ have to be licked all over very often, and they have to be carried from one part of the nest to another, according to the temperature. When the larvæ become pupæ they need no more food, but the cocoons have to be transported from place to place, and they have to be brushed. Finally, the workers may have to cut the wall of the cocoon to let the young ant out, and they may help to set the youngster on its feet. When there is real danger to the ant hill some of the workers rush into the interior, and the news passes from antenna to antenna. Then there is the familiar hurry-scurry—not a *sauve qui peut*, but "save the children," for each worker seizes a cocoon and does its utmost to remove it to a place of safety. Here the altruistic instinct reaches a high level.

Toilet

A good deal of time is given to personal toilet. There is an energetic use of comb and brush, of tongue and

mandibles, for ants are scrupulously cleanly. Forel tells us that even the most agile worker cannot wash its own head, and this necessitates a very interesting mutual toilet, which seems to be greatly appreciated. This is not to be confused with the way in which a hungry ant caresses a well-fed ant with its feelers, and induces it to disgorge something of its abundance.

The Stores and Chores

Another domestic industry is looking after the stores. The nutritive material has to be collected, but it may also have to be treated so that it does not sprout or rot; it has to be stowed away where moulds do not corrupt; it may have to be dried in the sun and re-stored. Sometimes it is made into biscuits, but that is another story. In unfriendly regions, like deserts, the storing industry is of great importance, and in the Messor ants of the Sahara there are deep and spacious underground galleries in which food is accumulated for the dry season. How quaint in this connection is a caste of worker honey-ants of the Garden of the Gods in Texas, where the crop is exaggerated to form a honey-pot. Half a hundred capitalistic honey-pots hang from the roof of the nest, and an ordinary worker keeps them in good humour. When compelled, an animated honey-pot disgorges its stores to two or three workers. That this strange adaptation is the result of a sort of enforced over-nutrition of large-sized workers is indicated by Professor W. M. Wheeler's experiments, for he has been able to produce the animated honey-pots by persistent over-feeding of young workers of the large-sized variety. Here we might also refer to those ants that keep cows in the form of green-flies or aphids, which they care for just as if they were domesticated animals. They milk them for the sake of the sweet juice which they readily exude. Then there is the story of the leaf-cutting ants.

Other Activities in the Nest

Another internal activity has to do with the guests and pets—the tiny aromatic beetles in particular, which are to the ants like Pekinese dogs to man. They are useless luxuries, looked after because they are pleasant.

On rare occasions there is a great to-do when a flitting has been decided on. Preparations have to be made for a huge mobilisation of Liliputians, for there may be 100,000 individuals in the nest of a Meadow Ant. In many cases, it must be understood, the ant community is one huge family; in other cases, as with the enormous ant hills of pine leaves in the Scottish Highlands, there are several large families in one community.

What goes on inside an ants' nest? There is resting, there is silent conversation, there is nursing in the wide sense, there is vicarious parental care, there is elaborate personal toilet, there is the care of stores, there is the petting of guests, and there are preparations for flitting. But these do not complete the list of internal activities. Thus, there is sometimes an exhibition of frolicsome gymnastics, when the inmates of the nest seem to let themselves go, indulging in extraordinary exercises which are either games or something horribly Freudian. The evidence is in favour of regarding them as spates of playfulness!

XIII

SLAVERY AMONG ANTS

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THE ways of a community of ants often appear like anticipations, sometimes like caricatures, of social behaviour among men. One thinks of the division of labour, the *esprit de corps*, the mutual aid, the obsession of the community's claims, the capitalisation of energy, the occasional domestication of other insects, and the occasional cultivation of plants. There is also the keeping of pets and the Liliputian warfare. Strangest of all, perhaps, is the fact that some ants keep slaves, as Pierre Huber discovered in 1810. To this naturalist, indeed, the fact of slave-keeping seemed so upsetting that he made a plea for calling the slaves "auxiliaries." It is interesting to inquire whether the word "slavery" which Huber rejected is justifiable or not, and the inquiry is made easier by the recent appearance of the fourth volume of Auguste Forel's fine book, *Le Monde Sociale des Fourmis* (1923). What are the facts of the case in regard to the strange custom to which the term slavery is applied?

Raids of Red Ants

One of the most plastic of ants, apparently showing intelligent profiting by experience as well as inborn instinctive dexterity, is the common Red Ant, which extends from Britain to Japan. Forel calls it *Raptiformica sanguinea*, but the first two syllables of this long name are

often omitted. In the middle of summer a large band of Reds leave their nest and search for a community of *Serviformica glebaria* or some other ant known from experience to be suitable. The expedition sets out in the morning, and may last into the afternoon. It is carefully organised without any fuss or flurry. When a suitable nest is found, the column of Reds spreads out into a crescent, or even into a circle, and the assault begins. The workers of the attacked colony rush out, each with a pupa or cocoon in its jaws in the usual altruistic fashion of ants. But the cocoons are snatched away, and there is soon a line of Reds carrying the captives back to the Red nest. The assault becomes keener, for the besiegers post guards at the gateways and prevent escape. They penetrate into the interior and steal pupæ from their very cradles. According to Forel, the aggressors rarely do any violence unless the attacked begin to bite, and the degree of recalcitrance differs from species to species. In some cases there is a vigorous sortie and a determined attempt to break through the ring. But the Reds are too numerous and too clever, and the capture of cocoons—it is, after all, a sort of "baby-snatching"—goes on until the Reds feel that they have enough. It will be understood that in this case, and in many others, in the New World as well as in the Old, there is no attempt to capture adults. Thus the slaves-to-be have no knowledge of any conditions except those into which they are hatched. We cannot but wonder whether they have any dim memories of having been larvæ somewhere else—that is to say in the parental nest. Forel reports an interesting case where the Reds captured some Meadow Ant pupæ and hatched them out into slavery in the usual fashion. But one day when the slaves were bustling about, working for their masters (or mistresses rather) they happened to meet their old mother. Whereupon they carried her to the Red nest, which happened to be at that time queenless. This looks at first

sight almost providential, but the inevitable outcome was that the Red Ant nest became a Meadow Ant nest. For the Meadow queen could not, of course, produce anything but Meadow offspring!

Amazon Ants

Slave-keeping is much marked among the Amazon ants, of which the European Polyergus is a good representative. For these Amazons are entirely dependent on their slaves; they cannot feed themselves and they cannot feed one another. Even in the presence of honey and other palatable food, they will perish of hunger, for the feeding instinct is in abeyance. They have to be fed. But put a single worker-slave in the midst of the Amazons and she immediately supplies food in response to their solicitations. Not only is active feeding in desuetude, but the Amazons are unable to attend to the brood, and they have lost the art of building. But we must not think of them as degenerates, for they are fearless fighters, and will allow themselves to be killed rather than retreat. With their large sickle-shaped jaws they grip the head or body of their adversary, and they are able to give a good account of themselves.

Forel has given us circumstantial details in regard to the raids of the Amazon ants, and there is no more remarkable chapter in the whole book of natural history. The raids occur in the summer months, from the end of June to the beginning of September; they usually start in the afternoon, when the temperature is comfortable, and last for three or four hours. There may be 375 to 1400 Amazons in an army—all of them "workers," if it is permissible to apply this term to such non-industrial militant creatures. The rate of the marching column, which sometimes has a length of two or three yards, may amount to about four yards in a minute, but it is much

reduced when the captured pupæ are being carried home. There is no field-marshal leading the army; on the contrary, the Amazons in the vanguard periodically pass back to the rear. This seems to involve the raiders in considerable indecision, and even when they utilise scouts who have discovered an underground slave-nest, the army sometimes loses its way. They call a halt with soundless signals and make a few tentative sallies, but if they are unsuccessful they become tired and discouraged, and turn homewards again. It is important that they should reach shelter before they are overtaken by the cold of evening.

Two Striking Details

Many of the details of the slavery among the Amazons are passing strange, but we must be content with mentioning two. The Amazon worker gets astride of the stolen cocoon and carries it between its front legs, for it can move most expeditiously in this fashion. But it cannot mount on the larger cocoons, which hatch into queens and males. From the fact, then, that the slaves are all workers, normally non-reproductive, it follows that the Amazon community cannot be overpopulated by slaves. It also follows that as the hard-worked slaves die off they must be replaced by fresh captures.

When food is scarce and the weather very hot the slaves sometimes mutiny. It gets on their nerves to be continually importuned for food by their militant mistresses. So a number of them combine to drag an Amazon to some distance from the nest. But the Amazon is so well armoured that it is difficult for a slave to do much harm, and the Amazon may be back at the nest before the revolutionary slaves have returned. If a slave should become too refractory and troublesome, the Amazon puts her big jaws round its head—and all is over! But

one is not sorry to learn that these revolts of the slaves do occur, and that there is at least one American species in which the slaves are sometimes successful in asserting their independence.

Evolution of Slavery

An interesting point in connection with slavery among ants is that there are various grades, forming an evolutionary series. Among the Reds, with which we began, it is not necessary to have slaves, though it is advantageous. Among the Amazon ants the utilisation of slaves is obligatory, for without them the Amazons would die. But between these two grades there are intermediate stages, such as are represented by the European and North American species of the genus Harpagoxenus. If there is anyone who still feels unable to adopt the evolutionary way of looking at things, he should give some study to the species of ant within the genus Strongylognathus. For the different species show many gradations. Thus the species *S. testaceus* has become practically a parasite, yet shows what Forel calls racial reminiscences of having had slave-owning ancestry! Another species makes slave-making raids by day and yet another species by night. In *S. alpinus* there is a droll climax, with which we may fitly conclude our story. The slaves are included in the raiding expeditions, and are used to make more slaves of their own kith and kin; if there is fighting to do, it is left to the slaves; the slave-owners' rôle is one of intimidation, though they sometimes condescend to carry their captives home.

XIV

BEETLES AND BUGS IN PARTNERSHIP

BEETLES AND BUGS IN PARTNERSHIP

ONE of the most interesting of recent natural history stories is Professor W. M. Wheeler's account of the social beetles that live in the swollen leaf-stalks of a peculiar leguminous tree (Tachigalia), indigenous to the Guianas. The plant occurs as a young shade form, a few feet high and with few leaves, and as a sun form, which is a real tree, with a crown of foliage at the summit of a very slender trunk, 40 to 60 feet in height. The hollow leaf-stalks are likewise tenanted by ants, and both the beetles and the ants cultivate coccid insects. As we shall see, there are other wheels within wheels.

A Triple Alliance

The keystone of the animate arch is the leaf-stalk or petiole of the Tachigalia. It is swollen in spindle form and is at first filled with juicy pith. This soon dries up and turns into loose fluffy amber-coloured tissue, which contains some very nutritive substance. Into this attractive shelter a queen-ant (one of four species) gnaws her way and closes the door behind her. She lays eggs and rears a brood of workers in the amber-coloured fluff. These workers open the door and go out and in. Soon, however, there are other inmates, which come in or are brought into the swollen petiole. These are coccid insects or mealy bugs, of a particular species, of course,

which attach themselves to the nutritive tissue and find an abundant supply of sap. So abundant, indeed, that the mealy bugs overflow and afford the ants a welcome supply of food. From one shelter another may be colonised, and the broods of several queens probably agree to live in harmony on the tree. If you knock at the door the workers rush out in angry crowds. An interesting point is that on any one tree there is only one kind of ant tenanting the swollen petioles. There are indeed leaf-cutter ants exploring, there are thief ants sneaking into the shelters, and there are non-aggressive ants who enter every hole and corner, but each tree has only one kind of ant-guest cultivating mealy bugs in the swollen petioles. So far then we have to do with a three-cornered inter-relation—the "myrmecophilous" Tachigalia tree, the special ant-tenants, and the mealy bugs that are middle-men between the two others.

It is time to turn to the beetle which Professor Wheeler found in the same inter-relation as the ant, *i.e.*, living inside the swollen leaf-stalk and utilising mealy bugs. It is a small narrow Silvanid beetle, dark chestnut brown, not very unlike some kinds of ants. Except when hungry or disturbed it is rather sluggish, and the observer never saw it fly. A pair of beetles resolve to set up house in a swollen petiole, either in an intact one or in a deserted one. In either case they make an entrance for themselves. If they have chosen a previously occupied house there is a good deal of cleaning necessary, but this is done somewhat perfunctorily by packing the refuse into the narrow ends of the spindle-shaped cavity. After things are tidy the female lays a few eggs which develop rapidly. Then enter the mealy bugs, which attach themselves to the amber-coloured tissue and are utilised by the beetles just as by the ants. But the beetles are able to feed on the vegetable tissue directly as well as indirectly. As the space is limited and as everything depends on the con-

tinued proliferation of the nutritive tissue, the inside of the petiole is kept in good order. The "frass" or undigested stuff, passed from the food-canal of the beetles and coccids, is disposed of in orderly ridges, and a little is used to build a circular tower round the opening. Here one of the beetles sometimes mounts guard, occasionally projecting his feelers and waving them about—a quaint sight on the surface of a plant! The inmates of the petiole may now consist of the parent-beetles, a dozen or so youngsters of various ages, and about as many mealy bugs. In some of the milk-eating tribes of Central Africa every child has its special cow, so there is usually a mealy bug for each young beetle. Soon, however, there is a second generation of beetles and the mealy bugs also multiply. There are deaths, of course, and consequent additions to the kitchen-middens in the narrow ends of the spindle, but the house becomes overcrowded. Then the beetles begin to flit, singly or in pairs, and new households are started in other leaves of the tree. It should be noted that while the larval and adult beetles are able to eat the amber-coloured tissue, they always solicit and utilise the sugary overflow of the coccids.

Only the female mealy bug of the Tachigalia has been seen—a squat pinkish creature, three millimetres in length, covered dorsally with white mealy wax. There are two pairs of minute dorsal ostioles which possibly secrete some attractive or repulsive substance. In some related forms droplets have been detected, but not in this species. The honeydew which the ants and beetles are so fond of is passed out from the end of the food-canal. If the mealy bugs are the cows of the beetles, in the sense in which Linnæus called aphids *vaccæ formicarum*, then the honeydew corresponds to cow-dung. When a hungry and thirsty beetle comes across a bug, it immediately proceeds to massage it with its club-shaped antennæ. It beats vigorously, using the feelers alternately, re-

minding the observer of an energetic piano-player, or, perhaps, of an exponent of musical slates with a gloved drumstick in each hand. Whenever a clear drop is emitted it is greedily swallowed. Then follows more percussionary massage. It is hard work, for the beetle has sometimes to beat for half-an-hour before it gets drops enough. Moreover the beetle sometimes tackles a dry coccid and may beat for an hour without getting a drink. An ant would never persist so long, but the beetle has not the brains of an ant. Many beetles and their larvæ too may crowd around one bug and drum on it together. But only one at a time can imbibe the clear droplet. It is no case of ilka beetle having its ain drap o' dew. So there is hustling and butting among the beetles. This strikes a note that is not instinctive.

Mutual Benefits

Where, it may be asked, do the mealy bugs' interests come in? Part of the answer is that they cannot get inside the petiole unless ants or beetles make a door. It is possible, moreover, that the massaging is good for their health. An interesting detail is that when leaves are cut off and become dry, the coccids drop from the grooves of nutritive tissue in which they were attached; their bodies become attenuated and somewhat shrivelled; the larval beetles suffer in the same way; the adults share in the general discomfort and restlessness. Then the beetles, both young and old, turn on one another and cannibalism runs riot for a brief space. But this does not occur in a state of Nature.

Wheels Within Wheels

Professor Wheeler soon discovered that the life of the beetles was not an easy one. They occur only in the

younger shade forms of the Tachigalia, for they cannot stand against the ants that colonise the larger tree-like forms of the plant. But before these arrive on the scene there are other enemies which invade the shelters. The worst of these is a little thief-ant Solenopsis that works at night and burgles the beetles' homes. It gets in at the unguarded door or bluffs the porter, and it devours the beetles both young and old. What it does to the mealy bugs is uncertain. They are compared by Dr. Wheeler to the cattle in a disturbed country; in most cases they change masters; occasionally they are devoured. But apart from the dangers incidental to the struggles between beetles and ants, the mealy bugs have enemies of their own—the predaceous larvæ of a small Coccinellid beetle, the maggots of a midge which enclose the bugs in a white web and devour them at leisure, and a Hymenopterous parasite which develops inside the bug. Truly wheels within wheels!

On a few occasions in his studies at Kartabo in Guiana, Professor Wheeler found the petioles of Tachigalia tenanted not by the beetle (*Coccidotrophus socialis*) whose ways have been described, but by another of different structure and similar habits. It seemed like a poor copy of the first—"a feeble, anæmic and harried species on the verge of extinction." The probability is that both kinds of beetles were at first vegetarian, that they found open petioles which ants had left, that they learned the palatability of the amber-coloured tissue, that they discovered from the ants the trick of utilising mealy bugs. But there is many a "perhaps" in the story. There are some other beetles that live in companies, but outside of the order of ants there are only two or three instances of insects utilising bugs as cows. The major problem is to picture the origin of that remarkable habit among beetles. The larval beetles are more alert, restless, and inquisitive than the adults; they massage

with great vigour; they have mouth-parts well suited for spooning up the sugary drops. Perhaps the habit began with them and they taught their parents. Perhaps, on the other hand, the adult beetles picked up the idea from the ants, and it should be noted that when a beetle enters an open petiole which the ants have deserted, it often finds willing coccids already there. Professor Wheeler hints at another hypothesis, but rejects it as rather far-fetched, that the habit may have arisen as a modification of a sexual activity, for the stroking of the female beetle by the male during the courtship is precisely like the stroking of the coccids. In any case we have to congratulate Professor Wheeler on his discovery of the facts concerning a singular pattern in the web of life. Perhaps there are fifty different threads meeting in the Tachigalia tree.

XV

INSECT MUSICIANS

INSECT MUSICIANS

In the course of evolution the voice has justified itself in many different ways, but its primary use was to express and invite love. The first words in the world were: "Arise, my love, my fair one, arise and come away"; and in simple-minded animals like frogs the only use of language is still the first one—to serve as a sex-call.

But there may be wordless voices. Just as an ant brings tidings to her neighbour by tapping its body with her antennæ, a sort of Morse Code, so there are many insects that express their love by means of instrumental music. Very energetically the males fiddle with one hard part of the body against another, say a leg against a wing, thus producing a chirping or trilling, technically called stridulation. This is very common in the cricket–locust–grasshopper–katydid order (Orthoptera), and it occurs in diverse ways.

A Variety of Instruments

In the burrowing mole-cricket, a "bow" on the underside of one fore-wing is rapidly rubbed against a "string" on the underside of the other fore-wing; and after a while the two wings reverse their mutual relations. In crickets the apparatus is more complicated but it is still confined to the fore-wings. The note is sometimes so shrill and penetrating that it can be heard a mile off. In locusts

and true grasshoppers there is a row of minute beads or pegs on the hind leg, and this row is scraped against a sharp ridge on the outer surface of the front wing. This sets the wing into very rapid vibration and a sound results. In the "green grasshoppers" and katydids the musical instrument consists of a file at the base of the left fore-wing and a ridge at the base of the right fore-wing. These work against one another, and the sound seems to be mainly due to the rapid vibration of the right fore-wing. The katydid musician has much pertinacity but a short repertory; over and over again, with occasional slight variations, he says: "Katy-did; O-she-did; Katy-did-she-did." It is interesting, however, that the diurnal music is a little different from the nocturnal, and a passing cloud may change the former into the latter. It has been shown with great precision that the number of calls per minute varies with the temperature. Indeed one can use the number of calls as a thermometer!

What the Music Means

We know precise details in regard to the various musical instruments used by insects, and the general meaning of the performance is clear. It is an expression and an evocation of sex-excitement. The male grasshopper fiddles away hour after hour; he does this with great zest; it means for him that he wants a wife. It is also certain that the females draw to the musicians; in some cases they answer softly back. For although stridulating instruments are usually confined to the males, they are present though not so well developed in a few females; and these have been known to use them. The main difficulty in interpreting the serenading is that we know very little in regard to the sense of hearing in insects. Their sensitiveness to vibrations is often exquisite but only in a few cases has their responsiveness to *sound*

waves been satisfactorily proved. Some ants that have musical instruments are nevertheless strangely deaf, and Forel has not been able to satisfy himself that they hear in our meaning of the word. In some cases, earlike organs are present, though the insects produce no sound. In one of the green grasshoppers there is no sound-producing instrument, but the creature turns upside down and drums on the ground with his tail. This suggests vibrations as much as sound waves.

It is probable, however, that in most cases the females hear the excited serenaders, for they certainly come. The instrumental music must be effective, for the instruments are very elaborate and their evolution must have taken a long time. The amount of energy devoted to the performance is extraordinary. Very interesting is the way in which groups of male "green grasshoppers" or Locustids shift their ground like itinerant musicians. They draw blank and they try another place, just as male corncrakes try field after field with their "creeking" call. It may be noted that a male mosquito answers back, by vibrations of his antennary hairs, to a tuning fork producing a note corresponding to the female's hum.

Cicadas and Other Instrumentalists

In Cicadas, which the ungallant Greeks called happy "in having voiceless wives," the musical instrument is on lines quite different from that of the fiddlers. A vibrating membrane on the under surface of the body is set in motion and kept in motion by the contractions of a special muscle, as a drum-head by strokes of the drumsticks. There is also a large resonating cavity which greatly increases the carrying power of the sound. Hundreds of male Cicadas combine in an orchestra, and the noise they make requires to be heard. Gradually the females draw near.

Among butterflies and moths there are occasional instances of the production of sounds by rubbing one wing against another, or by working on a wing with a leg, or by some other method. There is an Alpine Moth which produces when flying a very distinctive note, due to the vibrations of the margins of the anterior breathing apertures, and intensified by a resonator. When the female hidden among the grass *hears* the call of the low flying male, she trembles all over and flutters her wings, thus attracting his attention. Among beetles there is a widespread occurrence of stridulation, usually by working a rasp against a scraper, and it is interesting to find that when the instrument is present it is usually in both sexes, sometimes even in the grub. In one case at least the apparatus is confined to the female. We cannot profess to understand the meaning of sound-production in beetles; but in the case of the death-watch, where the male knocks his head against the wood, the tapping is surely a love-signal.

The sounds produced by rapidly flying insects like bees vary considerably from time to time, and may be used to express changing emotions. The sounds are in part due to the movements of the wings which beat with sufficient rapidity and regularity to produce a definite note. A fly may make three hundred strokes in a *second!* But apart from the wing-tone there is often a buzz or hum, due to the rapid vibration of a membrane or projection behind the breathing openings. But we have said enough to illustrate the variety of instrumental music among insects, and to make it plain that its usual meaning is to express and evoke what we may call, in inverted commas at least, "Love."

XVI

GARDENER INSECTS

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THE lover of insects, who is born not made, watches by an inexhaustible well of surprises. There is always something new in entomology. Thus Mr. William Beebe, the fortunate travelling naturalist of the Zoological Society of New York, a man with an infinite capacity for taking pains, but likewise with a knack for discerning the significant, has told us in his charming story of *The Edge of the Jungle*, how he broke into the underground city of the leaf-cutting ants, and saw hordes of workers chewing and chewing at the leaves which their fellows had brought in. But they were not eating them, as some naturalists had supposed; they were making them into a green paste on which is grown a fungus or mould. This fungus seems not to be known outside of the underground city of the leaf-cutter ants; they have the monopoly. It forms, apparently, the exclusive food during the subterranean life of the ants, but they probably "pick a bit" out of doors.

Mushroom-Growers

In his *Naturalist in Nicaragua* (1874) Thomas Belt got near the truth in regard to certain leaf-cutter ants. "I believe," he wrote, "that they are, in reality, mushroom growers and eaters." He pictured the leaf-cutting industry, the throngs of ants coming on their forest-

paths which reminded him of the streets of London, and the disappearance of the leaves into the recesses of earthen ant hills. But it was reserved for Möller to see the workers within the nest chewing and teasing the leaves into a tough paste, which is stored in large chambers and used as a bed for a fungus. The ants do not allow fructifications to grow, and they cut off the free threads of the fungus which tend to spread along the walls of the passages. The result of their labours is an abundant somewhat cauliflower-like growth on the beds of chewed leaf. Useless fungi are weeded out, but it is probable that the chewing affects the paste in some subtle way, so that it is suitable for the nutritive fungus but unsuitable for intruders. As the leaf-soil becomes exhausted it is removed in little balls, and fresh material is provided. Without the fungus the ants will starve, and without the gardener ants the fungus will run riot for a little and then die off. As we have said, it is not known outside the ants' nest. When a queen flies off to start a new community she takes a pill of the fungus with her in a pouch beneath her mouth. But in the new home there is no store of leaf-paste, for the queen has as yet no daughters to collect for her. What happens is remarkable. The queen plants out the fungus in the nest, and manures it with fluid from the food-canal. By-and-by her worker-daughters do the same, and it may be that the fluid, besides keeping the fungus growing, acts as a "selective steriliser." Soon, however, there is an importation of cut leaves, and a true garden is established. From an evolutionist point of view it is important to notice that there are other ants that grow fungi, and that the arrangements form a graduated series leading up to the climax we have described. Thus some use a variety of vegetable materials as a basis for the fungoid growth; they are not so specialised as those studied by Belt, Möller, and Beebe.

In some cases, such as the common Black Ant of Europe, that makes its home in hollow trees, there is often a particular kind of fungus growing on the walls of the passages of the nest. Its name is significant—Septosporium myrmecophilum, but, so far as we are aware (a necessary saving clause, since knowledge of these matters grows so quickly), the ants do not cultivate it, though they are said to relish the dew-like drops that appear on the ends of the fungoid threads. Such a case seems to us almost as interesting as the indubitable cultivation seen in the leaf-cutters. For it gives us a hint of the way in which the business might begin. Surely we should expect animals, especially on the instinctive line of life, to utilise rather than to invent. If a fungus naturally grew on the walls of the passages of the nest, the ants would tend—finicking creatures as they are—to eliminate it when disadvantageous; but they would naturally let it flourish when there was something in it that profited.

Termites as Gardeners

Everyone knows that termites, or "white ants," are architects of distinction, for they build great strongholds of salivated earth sometimes ten feet high, sometimes stable enough to bear a man's weight. Yet inside these ant hills there are nurseries and assembly rooms, royal chambers and store houses, passages and secret staircases, attics, too, and cellars. The fact is the termites are architects who care as much for interiors as for exteriors. But they are gardeners as well as architects; they are, to use Belt's phrase, "mushroom-growers." This is particularly interesting, because the custom of cultivating fungi must have arisen independently among the termites. For although we call the termites "white ants," they are not even nearly related to ants, and few of them could be called white. Some of them are so far from being white

that they are black! The fungus-gardens of the termites are seen at their best in Ceylon, and the characteristic feature is the construction of a maze of chewed wood with labyrinthine passages, on the walls of which the fungi grow. The labyrinth may be the size of a hazel-nut or the size of a man's head, but the idea is always the same —a multitude of passages, on the walls of which the fungus produces minute white spheres of very palatable quality. According to fungologists, these spheres should produce spores, but that does not usually come off in the termites' garden. But the termites have no doubt as to their nature, for that, from the termite's point of view, is not simply food, but dessert. Most termites are wood-eaters, and it must be a great relief to get a meal of juicy mould. Professor Henry Drummond—of evergreen memory—said that there were places in tropical Africa where it was dangerous for a man with a wooden leg to go to sleep, because the termites would reduce his dependable artificial limb to sawdust by the morning. A good story, no doubt, yet awfully true; for termites retard the spread of civilisation very seriously by their destruction of everything wooden.

From our present point of view the important fact is that termites, which are miles away from true ants, are also given to utilising fungoid growths in their houses, though they do not weed them so carefully as do the leaf-cutters. When we note that at least one kind of termite carries home segments of leaves, we again raise the problem—surely worth pondering over—of Nature repeating herself!

Ambrosia Beetles

Many beetles eat wood, but wood is poor feeding even when there is sap in it, for the sap that goes up the young wood consists of little more than water and salts. But

some beetles that bore in fresh wood have discovered how to grow a mould that yields what is called "ambrosia." The fungus lives on the wood and its sap, and it spreads on the walls of tunnels which the beetles make. The fungus collects and concentrates the food for the beetles and their grubs. In some cases the beetles do not eat the wood through which they bore; their food-canal contains only the "ambrosia" cells of the fungus. It is interesting to notice that the burrows of the ambrosia beetles are practically confined to the sap-wood, for the fungus would not grow in the heart wood where the cells are almost empty. And another very interesting point is that the cultivated fungus does not seem to form spores or other elements specialised for propagation. It must be disseminated by the gardener-beetles themselves, and the probability is that they infect a new tree with surplus vegetative ambrosia-cells which have passed out undigested from their food-canal. Yet it seems to be curiously difficult for the botanist to grow a successful culture of ambrosia!

Ambrosia Midges

A remarkable linkage of lives has also been demonstrated in the case of certain gall-flies which attack the flowers of mulleins, scrophularias, and capers. Here there are wheels within wheels. First there is the gall, an answer-back which the plant makes to the irritation which follows when the gall-midge lays an egg in the soft tissue. In most cases the stimulus seems to be the secretion that oozes from the mouth of the larva that hatches out of the egg of the gall-insect. In the second place, within the cavity of the gall there is a fungoid growth, first pure white and then grey or black, and the ambrosia-cells of the fungus are rich in starchy material.

The larvæ of the midge can obtain food from the wall of

the gall, but they usually thrive better when there is a vigorous growth of the fungus. None of these arrangements can be called perfect, however, for it sometimes happens that the gall allows of the growth of some weed of a fungus along with the ambrosial one—tares among the wheat, in fact. On the other hand, in his *Biologie der Pflanzen*, which includes a masterly discussion of all these linkages, Professor Neger insists that this symbiosis of gall-midge, flowering plant, and fungus is an old-established partnership, that works, on the whole, smoothly. Wherever the gall-midge spreads, its partner fungus goes with it—how exactly we do not know. For the midges are extremely delicate suctorial insects. It seems likely that the egg-laying organ of the female midge is infected with very minute spores of the fungus which sometimes appear on the surface of the plant. When the mother-midge lays an egg in the bud she unconsciously inserts a fungus spore as well.

We have kept to one kind of gardening activity, the cultivation of fungi, but we are not forgetting the work of the agricultural ants of Texas and other interesting linkages between insects and plants. What we have said is enough, in the meantime, to illustrate the widespread tendency in Animate Nature to bind one creature to another in the Web of Life.

XVII

THE FLOWER AND THE BEE

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ONE of the main trends of evolution has certainly been to link living creatures together, and one of the most important linkages in history has been that between flowers and useful insect visitors, such as bees. Useful, because the bees, in getting pollen and nectar for their own purposes, bring about the cross-fertilisation of flowers. And this cross-fertilisation improves both the quantity and the quality of the seed. Throughout long ages the flowers and the bees, if we may keep to bees for a moment, have evolved together; and they are now fitted to one another as hand to glove. In many cases they are nowadays indispensable to one another, for many of the flowers are so specialised that they cannot be fertilised except by bees; while, on the other side, bees are so highly specialised that they would all come to an end if there were no flowers that produced nectar.

Linkages Determining Lines of Evolution

This linkage, like many another, must in some measure determine the lines of further evolution; for the flower cannot safely change in a direction that would shut the door on its visitors; and the bees cannot safely change in a direction that would lessen their success with the flowers. The linkage is part of the well-woven web of life,

and it tends, like social linkages of a profitable kind, to keep things from sliding back. One must be cautious, however, for it is *possible* that without insects to pollinate them flowers might fall back on virgin-birth (or parthenogenesis), and that seems to be occurring in such very successful flowers as dandelions. They still produce pollen, but it is not used.

Bees Not Random Visitors

Inside the seed-box of a flower there are possible seeds or ovules, each containing a single microscopic egg-cell. The possible seed will not become a real seed, that is to say, an embryo plant, unless this egg-cell is fertilised. Similarly, no one expects a chick to come out of the unfertilised egg of a hen, and the egg must remain unfertilised if there is no cock in the yard. The fertilisation of the microscopic egg-cell of the plant depends on the dusting of the tip or stigma of the pistil with appropriate pollen-grains produced by the stamens of another flower of the same kind. Cases of self-pollination, as in peas, oats, rice, are in a minority; in most cases the pollen is carried from another blossom by insects or by the wind. A suitable pollen-grain, caught on the moist surface of the stigma, sends out a long tube which grows down to the ovule, and a male element—little more than one of the nuclei—in the pollen-tube enters into intimate orderly union with the microscopic egg-cell. In the maidenhair tree and a few other primitive seed-plants the male element is a freely moving cell, as it is in mosses and ferns and in most animals. In all ordinary flowering plants the male element is a more or less passive cell borne to the egg-cell by the growth of the pollen-tube. But in all cases the essence of fertilisation is the same, the intimate union of male-cell and egg-cell; this is the beginning of a new individual.

But this is only an introduction to what we wish to get

at—namely, an answer to the difficulty which must rise in the inquiring mind: How is it that the bees do not mix up pollens hopelessly as they pass from flower to flower? If a humble-bee dusts the pistil of a red-clover with the pollen of an aconite, the flower will not be "much forrarder." The answer is threefold. Some insects are specialists; they know their flowers "like good botanists," and they keep to them consistently. But, secondly, even when the insect is not a specialist it tends on a given journey or forenoon to keep to one kind of flower. What Aristotle observed, that bees do not fly at random from one kind of blossom to another, has been amply confirmed. The mouth-parts are suited for particular kinds of flowers; thus the hive-bee's tongue is not long enough to reach the nectar of the ordinary corolla of the red clover, which is easily reached by the humble-bee.

Moreover, of a summer morning, hive-bees pay considerable heed to the tidings brought in by the scouts, who inform them in some way or other, which flowers are most profitable at the time. It must be remembered that true bees deal very intimately with the pollen-grains; they moisten them with their mouths and put cakes of them in a depression or basket on one of the joints of the hind-legs, and the next joint is enlarged into a hairy brush. The pollen that is of use to the next flower is the loose dust entangled on various appropriate parts of the bee's body, appropriate in the sense that they knock against the stigma and deposit the grains there. Finally, it appears that foreign pollen dusted on to the stigma usually dies; only the proper kind of pollen sends out a pollen-tube. Add these three points together—(1) the specialisms of insect visitors, (2) their consistency on a given journey, and (3) the specificity of the pollen, which only grows on its appropriate soil (the stigma of its kind), and you have the answer to the question: Why is there not a hopeless mixture of pollens?

How do the Insects "Know"?

But the next question is: How are insects guided to the profitable flowers, or how do they recognize them as the flowers they are out to visit on that journey? The answers given to this question have been so discrepant, some authorities laying emphasis on colour-sense, and others on the sense of smell, and others on memories which associate certain shapes and textures with abundant nectar, and so on, that we are glad to avail ourselves of Professor Bouvier's *Psychic Life of Insects* (1922), which takes a critical survey of the known facts.

Many observers have concluded that bees pay most frequent visits to flowers (or even baited paper) with gaudy colours; but there has rarely been any firm discrimination between colour as such and the brilliance of the reflecting surface. What counts for most is conspicuousness against the green background, and bees are in some measure colour-blind! Uncovered flowers attract more visitors than the same flowers next door but shaded by leaves; highly coloured flowers with slight odour, like dahlias, attract more visitors than their fragrant inconspicuous neighbours, such as mignonette; conspicuous flowers get far more visitors than honey in a beaker next door.

The conspicuousness may depend on form and size as well as colour, as is shown by the attentions some butterflies pay to the big white flowers of the field convolvulus. The visits cease when the corolla is removed, though the nectaries remain intact. Yet after some time various kinds of insect visitors undoubtedly *learn* to come to honey-flowers whose petals have been cut off. This is a very suggestive fact.

Then there is fragrance, which certainly counts for much among hive-bees, for they are very richly endowed with smelling hairs. Darwin said that "bumble-bees

and honey-bees are good botanists" because they recognize the same kind of flower though the colour is different. They obey the advice of the father of botany: "Do not trust too much to colour." It is probably the characteristic perfume, mainly due to the flower's essential oils, that enables the bees to become "good botanists." Kerner saw a convolvulus hawk-moth fly straight to the invisible flowers of a honeysuckle over a hundred yards away. For a long range, then, where colour, brilliant surface, and shape cannot count as guides, certain insects, like bees and moths, may be attracted by odours diffusing through the air. When they come near, the other influences may tell. On the other hand, a bee attracted to a flower by its conspicuousness may turn away when it detects the perfume.

The Rôle of Learning

The question of the guidance of insect visitors to useful flowers has got into some confusion because different insects are differently attracted, and different flowers have different advertisements. Each case must be studied by itself. But there is more than that. Too little attention has been given to the capacity insects have of profiting by individual experience. They are not altogether instinctive automata; they are intelligent learners. They can attend and they can remember. They can build up associations between certain advertisements (colour, shape, fragrance), and good meals. Forel showed that bees *learn* to force their way into flowers covered up by leaves; Perez showed that bees *learn* to visit the scarlet pelargonium, which they dislike, provided a little honey is introduced for a while into the corollas; Bouvier and others have shown that hive-bees *learn* to profit by slits and holes which other bees have made as short cuts to the nectaries; and many observers have noticed that

bees *learn* to give up visiting flowers which promise well but are in reality disappointing. No doubt bees are dominated by their hereditary inborn instincts, but we fail to make sense of their behaviour unless we also give them credit for an intelligent criticism of advertisements.

XVIII

THE NATURAL HISTORY OF WAX

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WAX is not one thing but many, not any longer, they say, including sealing-wax. Most familiar is beeswax, and it may be said to be almost fundamental to the hive. For without the comb of wax it would be difficult to make a large store of honey. Wax-making is part of the division of labour within the hive, and it is an extraordinary performance. A number of bees take a good meal and then hang together in quiet clusters. In eight little pockets on the under surface of the hind part of the body a somewhat fatty secretion oozes out and hardens into a transparent platelet of wax. These fish-scale-like platelets project between four of the rings or segments of the abdomen. After a while, when the wax-makers are going to be comb-builders, they transfer the wax platelets from the pockets to the mouth, using their feet in so doing. The bees then use their jaws to chew the wax, and as some air gets entangled in the substance it comes about that the transparent wax changes to a more or less white colour, just as white of egg does when it is whipped. How the bees use this valuable material in building the beautiful cells with their tissue-paper-like walls, is familiar to all; but it never seems to become less wonderful. Bees are not Senior Wranglers, but they are excellent architects.

Nature and Origin of Beeswax

What is this beeswax and where did it come from? The secretion is a complex mixture. Very important

is an ingredient called cerin (cera, wax), soluble in hot alcohol and really a fatty acid. Much more abundant, up to 85 per cent., is myricin, not soluble in alcohol; it is what is called an "ester," and related to palmitic acid. There are hydro-carbons too, related to paraffin, and minute quantities of alcohols which the teetotaler cannot escape if he eats the honey-comb. We must not forget an acid that gives wax its characteristic odour. An interesting fact is that the wax made by humble-bees is quite different from that made by hive-bees; it consists mostly of an alcohol, not of an "ester." This illustrates what is called "specificity." Every animal is itself and no other, and this applies to its products, like milk and wax, as well as to the creature's blood and flesh.

As to the origin of the wax, the answer is clear—the bee is a chemical laboratory. The old naturalists, like Réaumur, seem to have thought that bees found wax ready made among the flowers, just as they find sugar. But it has been proved up to the hilt that bees manufacture wax out of their food, and that the sugar of the nectar counts for much more than the pollen in wax-production. Wax is a by-product of the chemical routine (or metabolism) of the bee's body; and, as in scores of other cases, the by-product has come to be a very important factor in life. For what would a worker hive-bee do without wax? Of course we are not pretending that we or any other biologists understand with anything like clearness how bees turn sugar into wax. Yet it is something to know that this is what they do.

Wax Made by Other Insects

But bees are not the only insects that make wax. Thus Chinese wax, which has been used for making candles since the thirteenth century, is exuded from a coccus insect that sucks the sap of the Chinese ash tree and some other plants.

It consists of a fatty acid (the cerin of beeswax), associated with an alcohol to make an "ester." Chinese wax is a brilliant white, pulverisable, crystalline substance. Not very different is the cochineal wax exuded by skin glands of the cochineal insect which frequents one of the cactuses (Opuntia). The fleshy parts of the cactus may be quite covered with a dense crowd of motionless female cochineal insects. These are enveloped in a glistening white wax in the form of fine threads or particles. The males fly about, and are not wax-makers, though the cocoons from which they emerged on the cactus are mainly composed of this plastic material. If we regard femaleness as implying a preponderance of up-building, constructive, assimilative, or, in short, anabolic processes, whereas the male is relatively on the opposite tack, we can understand that only the female cochineal insects are wax-makers. Wax is a regularised overflow of anabolic products. To state the case from the opposite side, drone bees do not make wax.

The oldest sealing-wax was made of beeswax, and its obvious value, besides adhesiveness, was in retaining an impression for a considerable time. This was replaced by shellac, which is produced by the females of another coccus insect, apparently as a protective covering. To the shellac there were added from time to time various adjuncts, and sometimes there are said to be more adjuncts than shellac. But if we understand the matter aright shellac is not a true wax.

In some parts of North Europe the ends of the twigs of the alder trees seem to be dusted in summer with white powder. When this is scrutinised it is found that the twig is covered with young green flies or aphids, like those on our rose bushes and bean plants. There are numerous glands opening on the insect's back, and the exudation of the secretion forms tiny spine-like prominences which make the creature like a miniature porcupine. An in-

quisitive naturalist collected over 100,000 of these aphids, and had the exudation analysed. It was found to be a true wax—mainly consisting of an "ester"—and its use appears to be that it protects the aphids from the rain, for the waxy secretion cannot be wetted! It is interesting to find the same sort of by-product being turned to very diverse uses; the beeswax forms cups for the honey, but in the alder-tree green fly the wax is a waterproof.

Vegetable Wax

But there are plant waxes as well as animal waxes; and some of the former, like myrtle wax and Japanese wax are commercial products just like beeswax. It has been noticed that various plants growing in conditions of drought have a waxy varnish over their leaves, which reduces the loss of water. The experiment of dissolving off the waxy varnish has been made; the result was a greatly increased loss of water. Some of the blue-gums or eucalyptus trees show the waxy exudation very clearly. In certain cases the waxiness is seen in the young leaves, but disappears later, doubtless for some good physiological reason. But the protection afforded by waxy varnish in the young leaves may be effected later on in some other way, for instance by an increase in the thickness of the cuticle. In general terms we may say that waxiness on the surface of leaf and fruit serves to check excessive loss of water.

Everyone knows the little green things in "caper sauce." They are the flower-buds of a Mediterranean shrub (*Capparis spinosa*), which is of some interest in connection with wax. The leaves are from the first somewhat waxy on their surface, but as the weather becomes warmer the secretion of wax increases and closes up the stomata. For the difficult time of drought the caper leaves reduce their loss of water to a minimum.

No one can think of wax without picturing something of the part it has played in human affairs. We think of wax forming ancient tablets on which momentous events were recorded all too transiently, or making seals for old documents that have been charters of freedom, or serving as a casting medium for great works of art, or building up candles which are beautiful unlit, and still more beautiful in their burning.

XIX

SHOWERS OF GOSSAMER

SHOWERS OF GOSSAMER

At the Fall of the year the links are sometimes covered for long stretches with quivering threads of gossamer. On certain slopes there is an almost continuous veil, and if one stoops down and looks against the light one sees what might well serve as a symbol of the Web of Life itself, except that it is not orderly. There is an intricate tangle of trembling lines, which cannot be mistaken for ground-webs or even for ground snares, for they are disconnected and run anyhow. They are never viscid, though some may be what Robert Louis Stevenson called "dew-bediamonded." We sometimes see them stretching over an acre of ploughed land or veiling many yards of hedgerow. Often they float against our face as we walk; they catch on our clothes like long hairs.

What is Gossamer?

On a fine autumn morning, when there is a slight breeze, several kinds of small spiders mount on posts and palings and tall herbage, and, standing with their heads to the wind, emit from their spinnerets a number of threads of gossamer. Four is probably the commonest number, each issuing from a spinneret with many spinning spools. We say "as fine as gossamer," but we should remember that each thread is the result of the coalescence of a multiple jet of liquid silk. According to the number

of spinnerets and spinning-glands used, the thread of gossamer will vary in tenuity.

When the threads paid out become long enough, the wind grips them; and when the tug is strong the tip-toeing spinner lets go. It is borne on the wings of the wind, supported by its silken parachutes, from one parish to another, from a crowded area to a place with more elbow-room. In some cases the spider is floated across a sheet of water, with the tips of its toes just touching the surface film. Usually, we think, the spider is upside down—as it is borne through the air. There is no doubt that the ballooning is a method of passive migration. It is congruent with the autumnal restlessness of many other creatures.

Subtleties of Ballooning

Careful observers assure us that there is often considerable subtlety in the ballooning. If the wind falls, the floating spider can pay out more silk, just as the sailor can unfurl more sail. If the wind rises, the spider can coil in part of its thread just as a sailor can take in a reef in the ship's sail. Mr. Blackwell, who wrote a fine monograph on British Spiders, published by the Ray Society about 1860, kept some spiders captive on a branch planted in a pot surrounded with a moat of water. He noticed that if there was a draught in the room the prisoners took advantage of it and emitted silk threads. If the free end of one of these caught on the far side of the moat, the spider fixed the near end on a twig and very carefully crept across the trembling bridge into freedom. When the whole pot was covered with a large bell glass, so that there was no draught, then there was no gossamer. It seems clear, therefore, that a current of air is necessary as the trigger-pulling stimulus of gossamer-making; and in natural conditions there is no flight of gossamer unless there is a slight breeze.

The Shower of Gossamer

Many of the threads of silk break off at the very start and are failures. Other threads are separated off in transit by gusts of wind and the like. Others again sink to the ground, or against the hedgerow, bearing their spinner with them. When thousands of little spiders spin gossamer some fine autumn morning, a shower of gossamer naturally results, but chiefly in the way last mentioned. The threads we see on the ground, on the hedge, among the grass, are threads that have fulfilled their purpose. It is interesting to notice that the essential facts in an explanation of a shower of gossamer were discovered more than 200 years ago by a boy of thirteen, Jonathan Edwards, who afterwards became famous as a preacher of rather terrible sermons and as the author of a treatise on the "Freedom of the Will."

Darwin on Gossamer

When Charles Darwin was on his famous "Beagle" voyage round the world—a Columbus voyage in a very real sense, for it led to the discovery of a new world—he made some interesting observations on gossamer.

When the ship was sixty miles from land, within the mouth of the Plata, the air "was full of patches of the flocculent web, as on an autumnal day in England. Vast numbers of a small spider, about one-tenth of an inch in length and of a dusky red colour, were attached to the webs. There must have been, I should suppose, some thousands on the ship." Darwin noticed that the æronauts were very active and very thirsty when they arrived on board.

Everyone has heard at least of the Indian Rope Trick. Some say that a rope is thrown into the air and that a boy climbs up it and disappears. We do not know the facts

of the case or their explanation; but we know that spiders throw silken threads into the air and sail away on them. We know that typically terrestrial creatures, without wings, make long journeys through the air. Animals are always attempting the apparently impossible and achieving it!

XX

PEARLS AND PEARLS

PEARLS AND PEARLS

THERE has often been argument over the question whether two things can be the same and yet different! The chemists tell us that indigo made artificially in the synthetic laboratory is chemically exactly the same as indigo made by the plant, and yet there are practical men who say that in the results of using the two substances there are slight differences. The same remark applies to perfumes and drugs which used to be procured solely from plants, but are nowadays concocted artificially. Chemically, and to all appearance, the artificial product and the natural product are the same, and yet there are connoisseurs who maintain that there are distinct differences, though of a subtle sort. The same question rises in regard to adrenalin made artificially in the laboratory and adrenalin produced by the suprarenal capsules of the animal.

There are two ways in which there might be slight differences between artificial and natural substances which have the same chemical composition. In the first place, it is certain that the artificial mode of production is quite different from the natural mode of production, and this may bring about slight differences in the virtues of the final result. In the second place, there may be infinitesimal traces of by-products associated with the naturally formed substances, but absent from the same substances made artificially. And everyone knows that a very little often goes a long way.

This introduction is relevant to the hot discussion of recent years concerning the value of undoubtedly fine pearls in whose making man has had a hand. They are so like the finest pearls obtained from the unaided pearl-oyster that even experts are not always able to distinguish the one from the other. To understand the question, which is of great interest, practically as well as theoretically, it is necessary to consider what may be called the different grades of pearl-formation.

Different Grades of Pearl Formation

Of no importance for our present discussion are the entirely artificial pearls—often quite beautiful—which are made in various ways, for instance, from the scales of fishes. They cannot be confused with any grade of pearl. They are frank imitations—very far removed from the bewitching balls of opalescent light with which a dusky princess used to play solitaire!

It is characteristic of molluscs that they are able to produce from the superficial layer of their skin a shell, whose innermost layer consists of nacre or mother-of-pearl. The shell is a non-living, non-cellular cuticle, made by the underlying living skin. As the mollusc grows it is continually adding to the free edge of its shell, enlarging its house as it enlarges its body. So it has got to moult periodically and begin afresh as is the case with crustaceans and other jointed-footed (Arthropod) animals. Besides the increase of the mollusc's shell along the margin there is increase in thickness by the internal deposition of lamina after lamina of transparent lime. Everyone is familiar with the beauty of mother-of-pearl on the handles of fruit-knives and the like, and it has been known since the days of Sir David Brewster that the beauty is due to the physical structure of the shell. There is a liquid transparency and a suggestion

of rainbow colours, but if you pound a little piece in a mortar it is soon a chalky powder with some organic matter intermingled. The chemical composition of mother-of-pearl differs a little in different parts of the same shell, and a good deal in different kinds of molluscs. A recent analysis of the nacre of the mother-of-pearl oyster (*Meleagrina margaritifera*) is as follows: Carbonate of lime, about 85 per cent.; organic matter, about 12 per cent.; and water, about 3 per cent. The organic substance which forms the matrix for the lime is called conchin or conchiolin, and it also occurs in true pearls. The chemical analysis of fine pearls shows a composition of about 92 per cent. of carbonate of lime, about 6 per cent. of conchin, and about 2 per cent. of water. The general similarity between the composition of nacre and pearls is of some importance, for the general trend of investigation is to show that the finest pearls are connected with mother-of-pearl by a series of gradations.

Imbedded Foreign Objects

The inside of the pearl-oyster shell is lined by the fold of skin called the mantle, and it has been known since ancient times that an object intruded between the shell and the mantle would become gradually enveloped in fine layers of mother-of-pearl. Thus the pearly sarcophagus of a little fish is sometimes found soldered to the inside of the mother-of-pearl layer; and from ancient days it has been the practice to intrude small bodies and retrieve them after they have become well covered with nacre. A modern improvement on this practice is to drill a hole through the shell and insert a rounded fragment of nacre, which may serve as a centre for independent deposition of fresh material. But there is no possible confusion between such imbedding of intruded objects and true pearls.

True Pearls

There is a large literature dealing with the natural history of pearls, and there is some diversity of opinion among experts. But, as it appears to us, the evidence adduced by Boutan and others is strong that a true pearl is always formed in a sac of skin, which usually encloses some irritant or stimulating nucleus. The nature of this nucleus varies. It may be a minute grain of sand or some other inorganic fragment. It may be the larval stage of a fluke or a tapeworm, and then the pearl is the sepulchre of an imprisoned parasite! Or it may be a blob of organic matter which has not been secreted in a normal way. Moreover, it seems that a dimple in the mantle may occasionally form a pearl without there being any visible nucleus at all. The general features in the making of a "fine pearl" are three—(1) that the seat of formation is a sac of the mantle epithelium, quite free from the shell; (2) that the cells lining the sac secrete concentric layers of carbonate of lime deposited in a framework of conchin (as Dubois said, the pearls require both carpenters and masons); and (3) that there is usually, though not necessarily, some visible nucleus which irritates or stimulates the walls of the pearl-sac. The fact is that a pearl is a nacreous formation occurring under abnormal conditions inside the sac of skin. It seems highly probable that the walls of the pearl-making sac are in a state of inflammation. It would be a mistake, however, to take the pearl too seriously as if it indicated a diseased condition. It is more comparable to the oak-apple formed on the twig as an answer-back to the irritation of the gall-insect. A pearl is like an animal gall—a response to something that has gone slightly agley.

Japanese Pearls

Till a short time ago, the most that man had done in the way of provoking the formation of pearls by bivalves,

like the mother-of-pearl oyster, was by the introduction of small bodies into the mollusc's skin. When the introduced body was a nodule of nacre the "pearl" that was formed had considerable merit, though it had not the lustre or opalescence of "the genuine article." But the aspect of the case has changed during the last few years since the ingenious Japanese experimenter, Mikimoto, succeeded in grafting into the skin of the pearl-oyster small pieces of the mantle-epithelium itself, with the result that pearl-sacs are developed which form pearls of great excellence. They are so fine that some experts at least cannot pick them out when they are mingled with others of entirely natural origin. Why a pearl formed around the nucleus of a parasite should be called "natural" while one formed around the nucleus of a piece of oyster-skin introduced by man is called "artificial" is beyond our understanding. But whether the response of the oyster to the fluke, or to a blob of organic matter, is finer than the response to a tiny fragment of skin ingrafted by man is another question. The proof of the pudding is the preeing of it, and the proof of the pearl is its lustre. So we are brought back to where we began: Can two things be the same and yet different?

XXI

THE PASSIONATE PIGEON

THE PASSIONATE PIGEON

PROBABLY no one ever got so near an understanding of pigeons as the late Professor C. O. Whitman, of Chicago, who devoted a great many years to making their intimate acquaintance. He is reported to have said that he did not think he could get much nearer the pigeon's point of view without metempsychosis. Unfortunately he died without publishing his results, and although his voluminous notes have been very skilfully edited by Professor Oscar Riddle and others (Carnegie Institution of Washington, 1919), one cannot but miss the welding together which Professor Whitman would have effected. We wish to refer to the volume dealing with behaviour, edited by Professor Harvey A. Carr, and to that part of it which deals with courtship. It may be noted that Professor Whitman worked not only with varieties of domestic pigeons, but with numerous wild doves, such as the mourning dove, the turtle dove, the bronze wing, the wood-pigeon, and the passenger pigeon (now extinct).

Courtship-Behaviour

Courtship is an early chapter—not always the first chapter—in the reproductive cycle of birds. It may be preceded, for instance, by the choice of a "territory" on the part of the male, as in the case of some warblers. It

implies biologically a heightening of the sex-impulses which makes the consummation more certain and more successful; but it may also have a psychological significance in binding the mates together by psychical bonds, as Mr. Julian Huxley has well illustrated in his fine study of the Great Crested Grebe. It is difficult to steer a middle course between exaggerating and depreciating the psychical side, but we venture to think that the latter is the greater danger. It should be noted: (1) that snatch sex-unions may occur apart from any courtship ceremonial and apart from any subsequent co-operation of the parties; and (2) that the courtship does not always lead up to sex-union as its immediate climax, for there is sometimes a well-defined "engagement" period, as in some wild duck. But only in a few birds has the courtship been studied as yet with sufficient care—with anything like the care with which Whitman observed his pigeons.

Everyone understands that the modes of courtship among birds are very varied, they include: appeals to the sense of hearing (song, twittering, cooing, crowing, calling, and even flapping of wings); appeals to the sense of sight (displays of plumage and ornaments, of agility and grace, rhythmically repeated movements such as bowing, curtseying and dancing; and "suggestive" movements, as when the male pigeon jumps right over the female; appeals to the sense of touch, as when the male chough strokes the female's head with his bill; chasing the female on the ground or in the air, or driving her towards the nest; and diverse subtler modes, some of which may have a symbolic significance, as when the Great Crested Grebes offer water-weed to one another; and here might be included the jousting of rival males in sight of the females, as in the well-known case of Blackcock, where there is much more than a display of movements.

The Impulses in Courtship

The impulse to sex-activity arises primarily from within, hormones from the reproductive organs setting the body aflame, but the fire is fanned by the mutual influence of the sexes, and it may be made to burn more intensely or more quietly according to extrinsic influences, such as those of diet and weather. In pigeons the impulses usually arise synchronously in the two sexes, but a lack of time-keeping may lead to a prolongation of the courtship or to a premature nest-building and egg-laying. This illustrates the *temporal variations*—lengthening of one chapter and telescoping of another—that often occur among animals and may have led in the past to the origin of distinct species, differing from one another like two playings of the same tune.

It is normal for the male bird to take the initiative in courtship, but the rule is often broken; and in this connection, as well as in regard to the futile mating of two hen-birds, it must be noted that the occurrence of "sex-intergrades," such as very masculine females, is well known among pigeons. One cannot help speculating whether these relatively abnormal individuals point the way to cases like the Red-necked Phalarope of Orkney and the Hebrides, where the female conducts the courtship while the male, whose plumage is duller, discharges the duties of incubation and also takes charge of the young. It is very interesting to find in pigeons individual variations which are like the initial stages of what has become a racial characteristic in the Phalaropes. We get a glimpse of evolution at work.

Courtship of Pigeons

The subtlety of animal behaviour is well illustrated by the courtship of pigeons. It does not last long in any one

cycle, but it is the very antithesis of perfunctory. It is often like an elaborate ceremonial. Of the items in the preliminary behaviour of male pigeons, the editor of Professor Whitman's observations gives the following summary—"billing or pecking at their own feathers on the wings and certain parts of the tail; preening and shaking the feathers; elaborate bowing and cooing; going to the nest and giving the nest call; approaching the mate; giving amorous glances; wagging the wings; lowering the head; swelling the neck; raising the wings; raising and spreading the tail and feathers on the back and rump; alternately stamping and striking the feet and wagging the body from side to side, and strutting with drooping wings. Charging and driving may be resorted to in the courtship. The male walks or rushes at the female, holds the head high, lowers the wings, exhibits excitement, elevates the back, erects the feathers, pecks perfunctorily or petulantly, clucks, and gives the driving coo."

This summary is too much like a composite photograph; it blurs the fact that the behaviour is often in a marked degree specific for particular kinds of pigeon. Thus the mourning-dove (Zenaidura) stamps with his feet before his desired mate, and the male Bronze-wing stands on tiptoe, lifting first one and then the other foot, raising one side of the body and then the other "in a way to exhibit his iridescence in different lights." Particular modes of behaviour marked in courtship may also be exhibited when the bird is emotionally excited in other connections, for instance by the intrusion of another cock; but the probability is that the primary reference of the varied movements is to mating. Two extremes of interpretation must be avoided. On the one hand, it seems indubitable that the enamoured male shoots his arrows of desire from a definitely bent bow, that he is seeking to arouse first the interest and then the excitement of the female. On the other hand, it seems certain that the behaviour exhibited

in the courtship is instinctive and specific for the race. It is probably the outcome of a long process of selection in the course of which ineffective displays have been sifted out.

So far we have dealt only with preliminaries. As the intensity of the courtship increases new elements enter into the behaviour. Along with bowing there is billing, along with curtseying there is jumping, the male fondles or hugs the female's neck, the male opens his mouth and the female thrusts in her beak. This last piece of behaviour is very interesting, for one must remember that birds are very thoroughly clothed creatures with little touch-surface, and one must also remember that both parents feed their young by receiving the nestling's beak in their mouth. As Professor Whitman pointed out, there is sometimes among animals an intimate linking of conjugal behaviour and parental behaviour. It is probable that the change of reference has been of great evolutionary importance.

Nesting

The courtship activities in pigeons usually extend over a period of seven days, but on the third day or so they begin to overlap the nesting activities. Sometimes it is the male, sometimes it is the female, who chooses the site; and the selection is marked by the bird's remaining near the chosen spot and giving the nesting-call to the mate. In most cases the female stays on the nest and works at its construction, the male bringing one straw after another, which is sometimes presented in a very characteristic way. In some kinds the straw-collecting like the subsequent brooding, is shared equally by the two birds. Sometimes the female remains on the nest all the night, but shares the brooding duties with her mate during the day. We must not, however, pass from the chapter

which we have selected, without noting the two important points that the sex impulses are suppressed during the period of incubation, and that the two birds remain faithful to one another throughout that time and for the whole breeding season. Exceptions occur, of course, but Whitman's prolonged observations indicate clearly that both the suppression referred to and the fidelity must be regarded as the rule.

Preferential Mating

There seems to be no doubt as to the reality of preferential mating in pigeons, for the cock's elaborate ceremonial may be met by persistent hostility and most discouraging indifference, while, on the other hand, the hen may leave one suitor for another who defeats him in a tussle. Perhaps the deep significance of it all is to make the eventual mating more racially successful by not making it too easy, which is just another way of stating Darwin's theory. In connection with preference, Professor Whitman noticed an interesting point, that the specific preferences exhibited by birds at maturity are to a large extent acquired, being dependent in part on the social environment in which the birds are reared. Young birds raised under foster-parents of a different species are very apt to prefer a mating with a member of that species to a mating with one of their own kind. This is important theoretically as an illustration of the way in which the mind of the creature is "made" as well as "born"; it is also interesting practically since it suggests one of the reasons why Professor Whitman was so extraordinarily successful in crossing widely separated species of pigeons. He recognised the psychological factor.

What has been said may serve as an illustration of the subtlety of behaviour in pigeons, but we must not think of them as all-round "brainy" creatures, or as compara-

ble, for instance, to dogs. From some standpoints they are "unutterably stupid." They may fail to recognise their own eggs a few inches out of place; they may injure their young in feeding them; they may cast the young bird from the nest along with the empty shells; they may incubate day after day on a nest where there are not any eggs at all. Yet they are not unintelligent, for evidences of a capacity for putting two and two together or of *learning* are not difficult to find. The fact seems to be that *along certain lines of activity*, pigeons follow somewhat too trustfully the promptings of instinct, and only occasionally ring up the intelligent capacities which slumber in the higher reaches of their smooth brains.

XXII

THE PROBLEM OF ANTLERS

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Of all the superficial differences between the sexes there is none more striking—not even the peacock's tail—than the antlers of the deer. They are restricted to stags with the single exception of the reindeer, where they occur in both sexes, and it may be that this is an exception that proves the rule, for in the great majority of cases the antlers of the female reindeer are much smaller than those of the male. It is possible that reindeer represent an exaggeration of a primitive condition in which small antlers were common to both sexes, as horns are in cattle. Or it may be, as others would say, that reindeer show us an interesting phase of evolution where distinctively masculine characters, originally sex-linked, are being transferred to the female as well. It is possible that the antlers in reindeer have some every-day use, common to both sexes, but the evidence on this point is discrepant.

An Expensive Decoration

From an economic and social point of view many prefer sheep-pasture to deer-forest, but it is impossible to refuse to admit a zoological and æsthetic thrill when we see a fine stag on the sky-line, with a magnificent set of antlers standing out as if in defiant declaration that everything is not utilitarian. For this is one of the problems that antlers present; they are very expensive structures

and yet we are not sure that they are of any use. They represent a lavish expenditure of organic material; they may weigh over seventy pounds; they form an encumbrance on the stately head; they have to be made afresh each season; they leave a red, raw patch when they fall off. It is by no means clear that they make effective weapons when stag fights with stag; they sometimes become entangled so that death conquers both combatants. If a stag that has lost his antlers is forced to fight during the ten days or so before the new ones begin to grow, he can give a good account of himself with fore-hoofs and teeth. In spite of fine pictures it does not appear that antlers are good weapons when a stag stands at bay against a pack of wolves. The usual answer is, of course, the Darwinian one—that the stags with the best antlers secure the largest harems, partly by their success in driving away rivals and partly by their conquests in another direction. But while we are not inclined to withdraw adherence from this theory, we must admit that there are some difficulties in its way. Thus aberrant hornless stags sometimes have a following of wives more numerous than their normally equipped rivals have been able to secure.

In view of these and other difficulties, it has been suggested by Mr. Mortimer Batten that the real use of the antlers is to make the stags conspicuous, thus drawing attention away from the hinds. If this could be substantiated it would be, we think, a unique case that one sex should have a character, disadvantageous to itself, yet established by natural selection because it secures the safety of the other.

Masculine Exuberance

We venture to suggest that all these theories are more or less wrong, and that antlers are exuberant outcrops

of the male constitution, of no particular use except in so far as they enhance the *tout ensemble* impression which excites the sex-interest of the females. To that end, however, they are at most accessory; their primary significance is as exaggerated expressions of virility, apt to transcend the limit of safety. For it is highly probable that they contributed to the disappearance of the giant Irish deer. Perhaps antlers have their counterpart in the huge, six feet long, spear-like tooth of the male Narwhal, for which again, no definite use is known.

Development of Antlers

The problem of antlers deepens when we inquire into their development, following a very striking investigation by the famous Glasgow surgeon, Sir William MacEwen (*The Growth and Shedding of the Antlers of the Deer, 1920*). In a buck's first year an outgrowth, or pedicle, rises from the frontal bone. This is a permanent structure which grows in girth during subsequent years. From the summit of the pedicle the antler grows in the second year, as the result of an extraordinarily rapid multiplication of bone-forming cells (osteoblasts), which extract lime from the blood and immure themselves into hard tissue. There is no bone-mending or bone-regrowth so rapid as the development of antlers. "The rapidity of growth in the antler is comparable with, but in excess of, that of the most rapidly produced tumours," and according to Professor MacEwen the multiplication of cells that goes on at the base of the antler is accomplished by a peculiar process of nuclear budding (an adjunct to the ordinary methods of cell-division). It is very interesting to find that "a somewhat similar process to nuclear budding in the antler is seen in rapidly-growing tumours, such as the sarcomata." This suggests that antler-

formation may be interpreted as a semi-pathological process which has become more or less normalised.

The pedicle grows out in the first year, the antler appears in the second year, and the first antler has only a single stem. The second antler has a stem and one branch or tine, and everyone knows that a new tine is added each succeeding year until maturity is reached, after which the growth becomes irregular.

Before a new antler begins to grow there is a greatly increased blood-supply in the skull and in the permanent pedicle. When growth begins there is, as it were, an overflow of cartilage and young bone from the upper surface of the pedicle—"in form like a young mushroom projecting from its stalk." The cartilage grows out distally, leading the way, while proximally, next the pedicle, it turns into the bone of the antler. "The more it contributes to the growth of bone, the farther it is borne away from the centre by the osseous deposit which it has so freely furnished." According to MacEwen the bone of the antler is usually formed indirectly through the intermediation of a cartilage or gristle phase, but direct bone-formation may also occur in the tines.

Meanwhile, as the antler continues sprouting, the skin is carried upwards with it, forming the hot, short-haired "velvet," rich in blood-vessels. It is an extraordinary phenomenon, this yearly extension of skin over a large surface in the course of the three months when the antler is a-forming. Outside embryonic development we cannot find anything approaching it except in cases where a newt replaces a considerable part of a lost leg, or a lizard most of its surrendered tail. There are numerous big blood-vessels in the velvet, supplying the food that admits of its rapid extension, and also keeping the growing antler-tissue suitably warm. The materials for the growth of the antler itself are brought by internal blood-vessels from the pedicle or stalk. It may be noted that ridge-

like outgrowths from the surface of the antler form grooves or gutters in which the skin-vessels lie, and that there may be a sparse interlinking of the deeper branches of the superficial blood-vessels with the network of thin-walled vessels in the interior of the antler itself. Branches of the Fifth or Trigeminal nerve from the brain run up the velvet, and make it exquisitely sensitive—another adaptation, for it saves the stag from knocking the still soft antlers against hard objects. The sensitiveness of the skin usually saves the growing antler from deformity, but it should be recognised that so long as the antler is actively growing it can within limits repair itself.

The Shedding of the Antlers

Perhaps the most extraordinary fact about antlers is that they should be shed. In a few cases, as among the Sambar Deer of the Far East, the antlers are shed at intervals of a few years, but in ordinary deer the huge structures are as transient as the leaves on the tree. Those of the Red Deer are usually dropped about February, and even the stag himself seems a little surprised! There is no doubt that they are often gnawed after they fall. As to the actual shedding, Sir William MacEwen tells us much that is full of interest. "At the birth of the new antler, provision for its ultimate separation is already foreshadowed, and preparation for its shedding may be seen during the period of its most vigorous growth." At the very outset the material that sprouts from the pedicle of the antler overflows and forms a projecting ring, afterwards called the corona, and about the level of this ring there occur the essential changes that bring about shedding. The edge of the corona, growing outwards, puts the skin and the superficial blood-vessels on the stretch, so that they eventually give way. This means cutting off the blood-supply of the velvet, which

dries, shrivels and peels off in shreds. Meanwhile, the bone-cells of the antler at the level of the corona multiply; they crowd, constrict and obliterate the internal blood-vessels, and an ivory-like barrier is formed which makes the antler dead tissue. But there is a third step, which is taken by the living tissue at the top of the pedicle. A soft granulation tissue is formed which gradually loosens the organic connections between the pedicle and the dead antler. This soft granulation tissue, which aids in the floating-off or sloughing-off of the antler, also furnishes material for the growth of its successor. There are crowds of osteoblasts, ready to begin their labours of bone-forming. As a final adaptation, it may be noted that the granulation tissue forming on the surface of the pedicle prior to shedding will tend to exclude germs and prevent suppuration, though that may occasionally occur.

The Puzzles that Remain

Can one understand the apparent wastefulness of the shedding of the antlers? Will it do to say that from the manner in which antlers are constructed they must be shed if a larger set is to be secured next year? Will it do to say that the manner in which antlers are constructed involves a dying away of tissue which might become a dangerous process *if it spread?* It is safer that the whole of the fine structure should be jettisoned. But we do not know.

We doubt if there are any "side-shows" in the animal kingdom more remarkable than this growth and shedding of antlers. The growth is so rapid and expensive, the result is so transient and superfluous. The potentiality which is part of the inheritance is actualised under the influence of hormones (chemical messengers) from the reproductive organs, and (excluding reindeer) the potentiality will not normally come to anything except in

masculine soil. Disturbances in the sex-life are often registered in abnormalities of the antlers, and, indeed, the whole story of antlers reads like a commentary on the biological expensiveness of sex. Then there is the suggestion that the growth of the antler has its counterpart in the abnormal growth of a tumour, and there is no doubt, at any rate, that the necrosis natural in the shedding of the stag's antler would be pathological elsewhere. Most striking of all, perhaps, is Sir William MacEwen's distinctive discovery of the preparations that are made from the very beginning of the antler's life for the shedding which is its end. It does not seem easy to get away from organic teleology!

XXIII

DANCING AMONG BIRDS AND BEASTS

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WE are not thinking of oddities like the dancing mouse, nor of pathetic creatures, like captive bears, which have been taught by man to "dance." What we have in mind are various animals, at different levels of organisation, which show off before their desired mates with an abandon of movements, sometimes rhythmic and almost always graceful, for which dancing seems the only word.

Thus, in the courting redshanks, Mr. Edmund Selous has told us how the male waves and flutters his wings above his back, nervously moving his coral-red legs, and uttering a little tremulous note. As a matter of fact, he is rather *behind* than in front of his desired mate, but the slightest turn of her restless head enables her to keep him in view. Of course, until or unless her interest is aroused the cock's dancing is of no use at all.

Dancing Ruffs

A similar absence of elaborateness is illustrated by the ruffs, which do so much in the way of mock-fighting. Mr. Selous writes: "Birds dart like lightning over the ground, turn, crouch, dart again, ruffle about each demure-looking, unperturbed little attraction, spring at each other, and then, as though earth were inadequate as a medium of emotional expression, rise into the air and dart around overhead, on the wing." The ruff darts at the

reeve, rebounds from her, darts back again, expands his collar, droops his wing, "as though he would overwhelm her with his gallant show, but then sinks prostrate at her side, and remains thus glued to the earth." Unless Nature is magical there is a high tide of emotion, as well as of bodily excitement.

Very striking are the descriptions given of the behaviour of the South American cock-of-the-rock, where one suitor after another shows off before a gallery of spectators. A clear arena is chosen and there the candidate, with orange-scarlet crest and plumage, dances a minuet, spreading his wings and tail. "Finally," says the late Mr. W. H. Hudson, "carried away with excitement, he leaps and gyrates in the most astonishing manner, until, becoming exhausted, he retires and another bird takes his place." In this case a somewhat subtle note is struck, anticipating certain native dances in which only one person performs at a time. There is a social and competitive aspect.

Joy-Dances

In his "Naturalist in La Plata," the late Mr. W. H. Hudson, of evergreen memory, gave a number of examples of dancing among birds. His interpretation differed somewhat from Darwin's, for he felt bound to conclude that in many cases the dance was not the cock's competitive display of good points, nor his endeavour to excite and rivet the hen-bird's attention, but was rather an expression of *joie de vivre* and exuberant vigour. An overflow of joyousness in high-strung creatures will naturally find artistic expression and racial individuality. Emotion and motion become closely linked. On the other hand, artistic expression at any level is very often useful, and from observations like those of Mr. Selous, and from what we have seen for ourselves, we are inclined to regard

Mr. Hudson's interpretation simply as a *supplement* to the Darwinian one, that the male's dance, like his song, is an expression of lust and love—the ever-intermingled clay and gold—and is useful in exciting and focusing the desired mate's interest. In some cases the best reward will be given to the male who deserves it most. And that is always well.

Transcending Sex

But there is good reason to believe that among animals—as certainly in man—activities which were at first directly linked to sex may transcend the fleshly trammels and acquire a new significance. Thus the voice, primarily a sex-call, becomes an instrument of reasonable discourse or a medium of purely æsthetic emotion. And it seems to us that this transmutation is hinted at in some of Mr. Hudson's cases. Thus he tells us of the singularly wattled, wing-spurred, long-toed jacanas that a flock of them will suddenly, in response to a note of invitation, leave off feeding and fly to one spot, where they form a close cluster and indulge in a strange display, both sexes taking part. They spread out their wings, "like beautiful flags grouped closely together; some hold the wings up vertically and motionless; others, half open and vibrating rapidly; while still others wave them up and down with a slow, measured beat."

Still stranger is the spur-winged lapwing's performance, which occurs all the year round, either by day or in the light of the moon. Two members of a pair—a married couple in other words—are joined by a third plover, the husband of another spouse. They welcome his presence "with notes and signs of pleasure." Of course, it is very difficult for us to get mentally near these creatures! Is this a friendly decorous visit, an old friend, perhaps a brother, coming to call on the married couple? Or is

number three a seducer coveting his neighbour's wife; or is he welcomed because he fans the fires of waning conjugal affection? Or is it just what Scots folks call a "diversion," nearer to play than to anything else? In any case it is *artistic*. Advancing to the visitor, the husband and wife place themselves behind him. "Then all three, keeping step, begin a rapid march, uttering resonant drumming notes in time with their movements. The march ceases: the (visitor) leader elevates his wings and stands erect and motionless, still uttering loud notes; while the other two, with puffed-out plumage and standing exactly abreast, stoop forward and downward until the tips of their beaks touch the ground, and, sinking their rhythmical voices to a murmur, remain for some time in this posture. The performance is then over and the visitor goes back to his own ground and mate, to receive himself a visitor later on." The data are obviously insufficient for scientific judgment, but it seems clear that animal behaviour is subtler than many people think.

The Dance of Spiders

It is well known that the courtship of spiders is in many cases very remarkable. The male is often a pigmy compared with the female; his advances are made with caution, for her temper is very uncertain. In the family of garden-spiders the courting is to some extent carried on by vibrating certain lines of the web—a method which has the advantage of leaving a way of retreat open. The males sometimes engage in mock-fights, and, like the ruffs, they do not hurt one another. In other cases what is most developed is a kind of dance. The male poses so that he displays his good points in the eyes of the short-sighted female, and may describe a semicircle before her, to and fro, many times. Or he may whirl madly round her until her coyness breaks down and she joins in

the dance. In one case the Peckhams counted one hundred and eleven circles made by the ardent male. In spite of his care the courtship is often fatal to the suitor, for the female may rush at him and end the dance with his death. The Peckhams write: "The female of *Dendryphantes elegans* is much larger than the male, and her loveliness is accompanied by an extreme irritability of temper, which the male seems to regard as a constant menace to his safety: but his eagerness being great, and his manners devoted and tender, he gradually overcomes her opposition." In the case of spiders, it appears highly probable that the courtship-dance serves to excite the interest and sex-instincts of the female, but she always remains more than a little "difficult."

Indian Ocean Calling-Crab

The Indian Ocean calling-crab disports himself before his mate on the shore, brandishing his brilliantly-coloured right claw, which is exaggerated out of all proportion. It is a far cry from this to the strutting and parade of peacock and pheasant, Argus and Tragopan, or to the more dance-like aërial displays of Birds of Paradise and humming birds; but throughout there is surely a touch of Nature that makes the whole world kin, and does not leave human dances out. Emotion expressed in rhythmic motion is common to all, but the gamut is a long one.

XXIV

MOTHERING AMONG ANIMALS

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WHEN we sit among the heather on a summer holiday we sometimes see a mother-spider hurrying through the jungle with a silk ball on her breast. That tiny ball, about the size of a pill, is a portable cradle; it contains the eggs and by and by the spiderlings. The mother-spider is very careful of it; if you are hard-hearted enough to take it from her for a little she will search for it diligently. For its sake she will risk her own life. Now this sounds a note which we hear all through the animal kingdom—the note of mothering. Sometimes clearly, sometimes dully, sometimes high-pitched, sometimes low-pitched, this maternal note is sounded—not universally, we admit, but very frequently. A cod-fish may produce two million eggs which are liberated into the universal cradle of the sea, and in such cases there can be no question of parental care. It is neither possible nor necessary when there is that superabundant multiplication which we call "spawning." The mother frog lays her thousand or three thousand eggs in the shallows of the pond, but she takes no care of the tadpoles. In these cases there is usually a prodigious infantile mortality, and the race continues because there are so many. One of the star-fishes, called Luidia, is said to produce two hundred million eggs in a year, and yet it is not a common animal. It is not given to every creature to be so productive as this, and in the course of ages all sorts of animals have

discovered a better way—to have fewer offspring and to take more care of them. So there have evolved many different forms of "mothering."

Many Forms of Maternal Care

We pictured the spider carrying about its silken bag of eggs, and does that not lead us to think of much higher animals where the young ones are carried about by their mother, both before and after birth? The kangaroo places her very helpless new-born babies in an outside skin-pocket developed round the milk glands and squirts milk into their mouths, for they cannot even suck! The tree opossum, that has no pouch, carries her family on her back with their tails curled round her tail. But they need to hold on tight when she jumps. The mother-bat carries her baby on her breast as she flies through the air, and this, it must be admitted, is a great achievement. The baby holds on with its thumb and also with its front teeth, which are specially suited for gripping the rough hair. We have all seen a cat shifting her kittens to what she thought was a safer place, and the same is seen among wild animals. The mother-squirrel shifts her family from a threatened tree, and the hare carries her leverets from one place to another when the fox is beginning to find out where she lives.

It is very interesting to notice how nearly related animals solve the same problem in different ways. The hare and the rabbit are first cousins; but the rabbit makes a bed of fur in the far end of the burrow and there brings forth blind and naked young ones, while the hare rests in an open "form" and brings forth furred young ones with open eyes. The rabbit's young are fairly safe because they are born in a burrow; the hare's young are fairly safe because the mother is so alert. What the country folk say, that she sleeps with her eyes open is true in idea,

though not in fact. It is the same with a human mother that when she sleeps, her ear remains awake to the infant's cry. How clever too is the hare's trick of taking a flying jump of several feet out of and on to the "form," so that the scent is broken and the fox is baffled.

Nests

The squirrel makes a big nest of moss and twigs on the branches of a tree; the harvest mouse weaves strips of leaves into a nest fastened to the haulms of wheat; the dormouse builds a nest with moss and fibres in a low bush in the thicket. Whenever we say the word "nest" what a crowd of pictures we see—the stickleback's nest among the water weed, the lamprey's stone nest in the bed of the river, the wasp's nest hanging from a branch, the humble-bee's nest in a mossy bank, and half a hundred more. And it always means mothering.

But the climax is, of course, among birds. Think of the weaver-bird's nest dangling from the tip of a branch overhanging a stream; the rook's nest swaying on the topmost branches of the tree; the sea-swallow's nest made of the consolidated juice of the mouth and glued on the side of a precipitous cliff; the nest of the thrush, so well plastered within and so well woven without; the two-roomed clay nest of the South American oven-bird—a hard structure as big as one's head; the beautiful feather-nest of the eider duck made of down from the bird's own body; and the nest of the Long-tailed tit made of over two thousand feathers which the bird has individually gathered. What industry, what skill, what patience—and not for self!

There is much more than nest-making to be thought of. There is the long patience of brooding during hot days and cold nights; there is the hard work of feeding the nestlings and the need sometimes to stand between them

and the sun or to ward off some living enemy; there is the protection of the youngsters when they become restless; and there is all the labour of instructing them in the art of life. Of course it is the meat and drink of the parents to do this for their offspring, but that does not lessen our admiration of the other-regarding impulses which are often strong enough to lead to a sublime self-forgetfulness.

Teaching the Young

Too little attention has been given to the amount of instruction which many birds and mammals give to their children. Take the otter, for instance, we know that the mother takes no end of trouble in schooling the cubs. She teaches them the A B C of woodcraft, *e.g.*, the sounds that are trivial and those that are significant for good or ill. She teaches them how to swim without noise and how to dive without a splash. She teaches them how to guddle for trout, how to dive full fathoms five after plaice, how to catch a young rabbit one day and a frog the next. She teaches them how to eat the various items on the otter's long bill of fare; how to get home without retracing their steps; how to lie *perdu* underneath the river bank while the enemy is searching all around. Surely all this mothering plays no small part in securing the otter's survival. And she joins in their games till they say good-bye!

The Ladder of Love

When we lift a stone from the shallows of a river and turn it upside down, we often find two or three leeches, some of them with exquisite markings. If we repress an absurd prejudice and turn the leeches upside down, we frequently find that some of them are carrying their

family about with them. This is parental care in very simple expression, and we must not embellish it with big words. We know, indeed, almost nothing about the leech's mind. We know, however, that the green sea-leech places its eggs in an empty shell and mounts guard over them, keeping them clean too, for many weeks, without apparently breaking its fast all the time.

Very common on the seashore are little sandhopperish crustaceans, Gammarids by name, which clean up every thing. They are unattractive to dull eyes, though they wriggle about sideways in a charming manner. The male carries the female about with him for a long time—a peculiarity not well understood. Now if you take a number of these little creatures in a saucer of sea-water, and leave them alone, you will see, in the summer time, a pretty sight. From beneath the shelter of the mother there issue forth many young ones, miniatures of their mother. They begin to explore round about, but—there, you have jarred the table and they have all taken refuge beneath their mother, as chickens under the hen's wings. This is on a higher level than the parental care of the brook-leeches, but it is on a low level compared with the patience of the nesting and brooding bird, compared with the almost human mothering that the otter lavishes on her children. There is intelligent mothering, and instinctive mothering, and there is a mixture of the two. There is also mothering so simple that we can only call it mothering. But the big fact is this, that at all levels of the animal kingdom, and through great reaches of it, there is abundant and generous mothering. We hear far too much about the undoubted success that rewards sharp teeth and talons, far too little about the undoubted success that rewards good mothering. Both are facts—but we hear too little of the latter. Perhaps only naturalists know how much of the time and energy of many different kinds of animals is devoted to ends which are race-preserving rather than

self-preserving, to endeavours which are for others rather than for self.

There are good human reasons for being gentle and kind, as well as for being strong and courageous; but there is a certain satisfaction in discovering that in the history of Animate Nature both have had their reward. Mother-care has made it possible for the animal to free its life from the burden of enormous families, and it has given the youngsters a better send-off on their adventurous journey. It has also enriched the life of the parents to have children not too numerous to be known and loved. And if this be true for animals, how infinitely more for mankind.

XXV

MILK

MILK

It was at Harry Lauder's long ago, when the minstrel spoke of meeting a man and going round the corner "to have a drink." "A drink o' milk," he explained; and some man in the audience laughed incontinently. "Ay," said the genius, "a drink o' milk, I was sayin'. And it was the first drink *you* had, my man." As the audience cheered the sally, the minstrel had his victim once again: "And may be it'll be the last drink, too, that you'll hae." From the *vita minima* of the new-born to the *vita minima* of the moribund—milk!

An Extraordinary Fluid

It is certainly one of the most extraordinary of all fluids, containing all the three kinds of food, proteins, fats and sugar, with water and salts thrown in. In cow's milk there is 3—4 per cent. of protein, 4 of fats, 4.4 of sugar, 0.6 of salts, and the rest water. One of the interesting features is the specificity of milk, for the dolphin's has 43.8 per cent. of fat, the reindeer's 17.2 and the rabbit's 16.7. The reindeer's milk has 10.4 of proteins, the dolphin's 7.6, the camel's 4, ass's milk has 5.7 per cent. of sugar, goat's 4.9, and reindeer's 2.8 per cent. This diversity of composition is related, of course, to biological conditions; thus the young reindeer in a cold climate requires a lot of fat; and the young rabbit that doubles

its weight in six days after birth requires much more nutritious milk than the human baby, who takes 180 days to accomplish the same feat. As the baby dolphin is born and suckled in the sea, it probably requires all the extraordinary proportion of fat which we have just noted in the composition of its milk. One of the big facts of life is specificity; down into details every organism is itself and no other. The blood-crystals of a donkey are different from those of a horse, and goat's milk is quite different from sheep's.

Adapted to Special Needs

Another big fact of life is adaptation; at every corner we meet a fitness. One does not, indeed, make any special marvel over the fact that the dolphin, which goes in for blubber-making like all other cetaceans, should have much fat in its milk. For the milk is a product of secretory cells that get their raw materials from the blood and the lymph; and if the dolphins have a predisposition in the way of fat-production, it is quite natural that it should show in the milk. At the same time, the fattiness of the dolphin's milk fits in very well. And speaking of adaptations, we are reminded that the first milk the new-born mammal gets for a short time after birth is quite different from the ordinary milk. It is much richer in proteins, and has much more cellular débris; one would think it must be very useful at the critical transition from ante-natal symbiosis to babyhood. No doubt there are physiological reasons for it, but it fits in very well, does it not?

Natural History of Milk

There are many very interesting Natural History facts about milk. It is of course a prerogative of mammals

to give milk, for "pigeon's milk" does not count, not being a secretion. It is Nature's way to make a new thing out of an older thing, and the milk-glands are specialisations of more ordinary skin glands, like the sebaceous glands that keep the fur sleek or the sweat glands that get rid of saltish water. In the two egg-laying mammals the milk-glands are very peculiar, and one view is that they are nearer the sweat-gland type, while those of other mammals are nearer the sebaceous type. In these two primitive mammals—the Duckmole and the Spiny Ant-eater—the ancestral reptile still lurks; and it is very interesting to find that the young one simply licks a patch on its mother's skin where the secretion exudes by numerous pores. There are no mammæ to suck. Only in the case of the Spiny Ant-eater has the "milk" been studied carefully. It is very rich in proteins; it has little or no sugar; it has no phosphate salts. It is very different from ordinary milk.

We must refrain from describing how the marsupial mother forces the milk into the mouth of its offspring and yet does not drown it; or how the whale, suckling in the sea, gives its huge baby a big mouthful at once. We must not linger, for there is a more urgent story to tell.

Apart from monotremes, which we do not know enough about, all young mammals are suckled on milk, and they get plenty of it. A puppy doubles its weight in nine days, a lamb in fifteen, and in these cases the milk is much richer in protein and fatty material than is the milk supplied to the calf, which grows much more slowly. This is the kind of fact that is interesting to the biologist, but it becomes of commanding importance when the question is of the supply of milk to children. It has been demonstrated that children in Great Britain, for instance, do not get nearly enough of fresh milk, and the practical questions that arise are how they can get more, how the quality of what they get can be maintained or improved

and whether there are any substitutes which can make up for the deficiency. These questions are far beyond our province, but there is a general biological question behind them, namely, what is there about milk that gives it such pre-eminence as a food for tender years?

Why Pre-eminent as Food for the Young?

Part of the answer is easy and part of it is difficult. Mammals have succeeded above all other creatures for a variety of reasons—and one of these reasons is *milk*. For this fluid is a handy form of food, available whenever the mother is get-at-able; it is readily digestible and eminently well suited for *gastric education*. The young fox or stoat or weasel must suck milk for many days before it is able to make anything of even prepared flesh, such as the mother brings it in due season. A young mammal is often very far advanced at birth, especially if it is born in conditions where it must live facing risks; it is a clamant creature with large needs; how are these to be met? The appropriate food is often unprocurable except after an apprenticeship to woodcraft, and that takes time; so milk fills the gap. But the suckling period is often very hazardous at the best, and thus we see the value of hurrying on the post-natal growth, which milk seems to be pre-eminently capable of doing. Even if the critic should say that eating grass does not require much apprenticeship, it would be fair to reply that grass is not an easily digested food, and, so far as we know, the cellulose is not digested at all in backboned animals, but is broken down into sugars by a whole army of bacteria. We do not suppose that the lamb is born with this army. So it must suck milk.

We must get into closer grips with the question, Why is milk such a valuable food for tender years? Milk contains proteins, such as casein, and proteins are the only kinds

of food that afford materials for building-up and sustaining the living tissues of the body. But all proteins are not the same; some are much more valuable for growth and repair than others are. It has been shown that milk proteins are the very best that young mammals can get; 63 parts per cent. are retained for growth; whereas of wheat-protein, only 25 per cent. can be utilised for this purpose. Surplus protein material can hardly be said to be storable, unless as part of the living tissue. Therefore, a daily supply of protein food is essential.

Then there is milk-sugar, which supplies energy for muscular activity and heat for maintaining the temperature of the body. This animal heat is necessary if the chemical processes are to go on smoothly and at the proper rate. The milk-sugar that is not at once used up can be stored in the form of animal starch or fat.

Then there is the fat of the milk, which again affords an indispensable supply of energy for muscular activity and of heat to maintain the body temperature. The fat, as everyone knows, is storable. The salts in the milk are essential for bone-making and also for keeping up a proper balance in the fluids of the body. Finally, the milk includes several accessory food factors or vitamins, mysterious substances or properties which are indispensable to health. It is plain, then, that milk is *a perfect food*, and as grown men can get good substitutes for it, they should leave it, when it is scarce, for those who cannot —for babes in particular.

XXVI

COMMENSALISM

COMMENSALISM

MANY animals live as encrustations on other animals—epizoic they may be called. Acorn-shells and worm-tubes may be seen growing on a crab's shell and a zoophyte even on a fish. One of the strangest cases is that of a big bunch of barnacles fixed to the tail of a sea-snake. Sometimes the encrustations become so heavy that they seriously handicap their bearer, sometimes they serve as a mask, but in most cases the epizoic growths have neither a harmful nor a beneficial significance. This is not what is meant by commensalism.

Quaint Associations

A curious inter-relationship has arisen between slender fishes called Fierasfer and the sausage-like sea-cucumbers. When the fish touches a sea-cucumber it feels its way to the hind-end and then suddenly thrusts the tip of its tail into the food-canal. It then insinuates its whole body in a very deliberate way and disappears for a while into its strange shelter. For that is what the association seems to mean. The Fierasfer sometimes utilises a large bivalve, but it does not try to get into creatures in which there are not fresh currents of water. It is a light-avoiding fish, related to the sand-eel, but it cannot endure stagnancy. For such a case and for the little fishes that swim about under the umbrella of a large medusa the term shelter-

association will perhaps suffice. This is not what is meant by commensalism.

It is difficult, however, to draw a firm line where shelter stops and something more begins. There is a brilliant Indian Ocean fish, called Amphiprion, about two inches long, that lives in association with a large reef-anemone (Discosoma). So far as we know, it has not been found away from the sea-anemone, and if it is removed it soon dies. It lives among the tentacles and retires into the food-canal on the slightest alarm. As Mr. Banfield says in his delightful *My Tropic Isle* (1910), "it is almost as elusive as a sunbeam, and most difficult to catch, for if the anemone is disturbed it contracts its folds and shrinks away, offering an inviolable sanctuary." The benefit to the fish is plain enough, it finds shelter and crumbs, but is there any benefit on the other side which would bring the case within the rubric of commensalism? Many sea-anemones are in the habit of stinging and seizing small fishes which intrude inquisitively or incautiously, but Discosoma does not seem to object to Amphiprion. It has been suggested that the brilliant colouring of the fish may serve as a lure, but it seems more probable that the movements of the fish in and about the sea-anemone help to keep up useful currents of water.

Mutual Benefit Societies

Commensalism at its best is a mutually beneficial, external partnership between two animals of different kinds. The typical case is the familiar association between a hermit-crab and a sea-anemone. The hermit-crab, having a very vulnerable tail—an unusually large Achilles' heel, borrows the shell of some sea-snail, such as the whelk or buckie. In certain large kinds of hermit-crab it is the rule to put sea-anemones on the back of the borrowed shell. This is done in a very deliberate way, the hermit-

crab coaxing the sea-anemone off its substratum, gripping it by the middle, turning it upside down, and then holding it in the proper position on the shell until it grips. When a hermit-crab has grown too large for its whelk-shell, it has to flit, leaving the partner sea-anemones behind. On such occasions it has been seen shifting the anemones from the old shell to the new. The sea-anemone masks the hermit-crab's bad reputation (for there must be something corresponding to this) for voracity and pugnacity, and it has batteries of stinging-cells that may be useful at a crisis. The hermit-crab carries its partner or partners about, whereas ordinary sea-anemones are sedentary; and there are crumbs that float up to the sea-anemone's tentacles from the crustacean's often-laid table. The advantages are on both sides, and *this is typical commensalism.*

There is much that is interesting in this well-known type of commensalism which would reward further experimentation. Thus there are cases where the sea-anemone is almost always found associated with the hermit-crab (*e.g.*, the British *Adamsia palliata* on *Eupagurus prideauxii*), and there are cases where the sea-anemone plays an active part in re-establishing a lost partnership. Colonel Alcock has described a quaint case where the anemone settles down on the hinder part of the young hermit-crab's tail, and the two creatures grow up together in a most intimate manner, the spreading sea-anemone forming a "blanket which the hermit-crab can either draw completely forward over its head or throw half back as it pleases." This is striking enough, but what are we to say of cases like the shore-crab, Melia, where a sea-anemone is carried on each of the great claws or forceps and brandished about as if it were a weapon? This is uncommonly like one animal making a tool of another. Our interest increases when we learn that if the crab is robbed of its partner it appears to be greatly agitated. "It hunts about on the sand in the endeavour to find it

again, and will even collect the pieces, if the anemone is cut up, and arrange them in its claw."

Experiments in Evolution

When we take a broad view of the associations between different kinds of animals, we get the impression that a good deal of experimentation is tolerated as long as it is not disadvantageous, and that when some marked benefit accrues the association becomes fixed and elaborated. Thus various kinds of zoophytes may be found growing on the shells tenanted by hermit-crabs, and most of them are neither here nor there. But in certain cases the note of utility is struck and Nature's sifting begins. We see this in the zoophyte colony Hydractinia, very interesting on account of the polymorphism or division of labour among its members, which often grows over a hermit-crab's borrowed shell. The association is profitable to the zoophyte which is carried about and also gets crumbs from the hermit-crab's meals. The association is profitable to the hermit-crab, which is masked by the innocent zoophyte growth. But there is another advantage, that the zoophyte lightens the hermit-crab's borrowed shell by absorption, and that it enlarges it at the mouth by an extra growth of its own, so that the crustacean can retain its house for a longer time—and the longer the better for the Hydractinia!

Cases of commensalism and allied associations are very interesting in themselves and in the problems of animal behaviour which they raise, but they also disclose a widespread tendency throughout animate Nature—the tendency to link one organism with another in the Web of Life. They illustrate the integrative trend of organic evolution. If the struggle for existence is a formula for all the answers-back that living creatures give to environing difficulties and limitations, it includes not only competition but

co-operative tactics as well. Struggle includes symbiosis. Just as there is correlation of organs in the body, so there is correlation of organisms in the economy of Nature. Not only have we to think of epizoic encrustations, of shelter associations, of masking, of external commensalism, of internal symbiosis, of parasitism and the like, but of the linkage between flowers and the pollinating insects that visit them, between fruits and the birds that distribute their seeds, between ants and aphids, between liver-fluke and water-snail, between rats and plague, between trout and orchards, between malaria and minnows, and so on endlessly. As Locke wisely said: "Things, however absolute and entire they seem in themselves, are but retainers to other parts of Nature."

The Value of Linkages

The general suggestion that stands out is this: It looks as if there were in animate Nature a tendency to establish inter-relations, and that these inter-relations (if they are not on the parasitic tack) must make for progress. The way in which the progress is brought about is twofold, first, inasmuch as the working out of a linkage means an external registration of some step—a step worth taking if the linkage stimulates—and, second, inasmuch as the external system of inter-relations, always becoming more intricate, forms part of the sieve by which further new departures or variations are sifted. There has been an age-long evolution of sieves, which partly accounts for the progressive evolution of the sifted.

XXVII

SYMBIOSIS

SYMBIOSIS

This is a good term, worth retaining in a more or less strict usage, to denote a mutually beneficial internal partnership between two living creatures of different kinds. For mutually beneficial *external* partnerships, such as that between some hermit-crabs and sea-anemones there is the satisfactory word "commensalism," literally "eating at the same table." For an association with the benefit all on one side there is the term parasitism. It seems desirable to keep "symbiosis" for a mutually beneficial internal association, and there is in the word ("living together") a suggestion that the linkage is intimate, affecting the metabolism of both partners.

Lichens as Dual Plants

It was the botanist De Bary who first applied the term symbiosis to the partnership illustrated by lichens. For he was one of those who established the interesting fact that these encrusting plants, so familiar on rocks and trees, are dual organisms. They represent a firm, consisting of fungoid partners, which fix and absorb and protect, and of alga partners, which have chlorophyll or some allied pigment and are able to build up carbon compounds. The fungus partners, which supply the water and salts, sometimes get the upper hand and absorb their partner algæ, without which, however, they cannot continue to live.

The alga partners sometimes manage to get along in water without their associated fungus, but they flourish best in symbiosis. It is interesting that the fungus partners, which normally absorb water and dissolved salts, sometimes take to absorbing decayed organic matter (sinking to the saprophytic diet which many fungi illustrate), and may go further and take to absorbing food from the living tissues of a tree (sinking to the parasitic mode of life, which is also very common in the class). Lichens thus show how certain fungi have found a new *modus vivendi* by entering into co-operation with certain algæ; but from this partnership, as we have seen, there are occasional relapses.

The Secret of the Heather

Everyone recognises that heather grows well on poor and unpromising soil where relatively few other plants will thrive, but what is the heather's secret? It has a partner fungus which sends its threads not only into the cells of the root but into stem and leaves and even into the seed-box. The fungus acts as the intermediary between the heather and the soil; it absorbs water and organic material; it is perhaps able in some measure to fix atmospheric nitrogen. In any case, the heather has been able to effect a compromise with what was probably to start with a predatory intruder; indeed, the compromise has gone so far that the heather cannot thrive without its partner. This, again, is symbiosis, and it is now known to occur in a large number of plants. In many cases, such as beech and pine, the partner fungus or mycorhiza confines itself to the outside of the root, forming a dense, absorbing felt-work, which though not indispensable to the life of the tree is certainly valuable. The fungus absorbs water and salts and organic materials from the soil and passes these on to the tree; the benefit it gets in return is a

supply of carbohydrates from the root. As the threads of the fungus do not usually penetrate into the root-cells the partnership is external in this case, while it was internal in the case of the heather, which shows the impossibility of hard and fast definition, for the physiological condition is the same in both, and both must be included as forms of symbiosis.

The linkage becomes subtler in some of the orchids, like the bird's-nest orchis of our woods, for while there are cells in the host-plant which live in partnership with the spreading fungoid filaments, there are others of a very peculiar type which attack and digest these. In this way, as Professor Bower puts it, "the intrusive fungus is kept within bounds, and headed off from tissues of vital importance"; and the digestion is in itself profitable, for the fungus has worked up valuable nutritive materials in its threads. It is a curious case this—of eating the cake and yet having it, and the orchid's digestive cells are strangely suggestive of the amœboid phagocytes which ingulf and digest intruding bacteria and perform other useful offices in our body.

Root Tubercles

An interesting form of symbiosis is seen in the root-tubercles which occur on almost all leguminous plants and in some other cases. It seems that motile bacteria pass from the soil into a root-hair and spread in a thread-like trail from cell to cell. In the rind of the root, where a rootlet would arise, the bacteria provoke the bean or the clover, or whatever it is, to form a gall-like tubercle, and in this they multiply apace, becoming curiously branched and turgid "bacterioids." In some way or other, in the presence of the sugar and proteins of the root, they are able to fix free nitrogen from the air, and this goes to the enrichment of the host-plant, which is continually digest-

ing its partners by a sort of vegetable phagocytosis. The partnership is so thoroughly established that the leguminous plants cannot thrive without their bacteria; it looks like another case of making a friend of a foe. The fixation of free nitrogen means a great improvement of the soil, and it is certainly an admirable performance however it is brought about. What man does by means of dynamos which send high-tension arcs through the air, the symbiotic bacteria do very quietly in the roots of the beanstalk.

Plants in Partnership with Animals

Among animals also symbiosis is common. Almost all the minute Radiolarians, with exquisitely beautiful skeletons of flint or of acanthin, have partner algæ in their transparent living matter. They float on the surface of the open sea, often in countless numbers, and the variety of their kinds is legion—over 5,000 species having been described. Perhaps their success is partly due to their symbiosis. In the sunlight, the partner algæ can utilise the carbon dioxide which the animal protoplasm produces, liberating oxygen which must be useful to their bearer. The algæ are capable of photo-synthesis and the carbon compounds they build up can be utilised by the Radiolarian. The two kinds of creatures work together as if they formed a firm. The symbiosis is a mutual benefit society.

The same kind of co-operation is illustrated by a number of green Protozoa, in cases where the green colour has been shown to be due not to the animal having learned the plant's secret of manufacturing chlorophyll, but to a partnership with minute algæ (Zoochlorellæ and Zooxanthellæ). There are probably a few green Protozoa, like Euglenids and a green bell-animalcule, which have chlorophyll of their own, but most green animals are instances of symbiosis. This is true, for instance, of the green species of Amœba, the green fresh-water sponge, the green Hydra,

some green sea-anemones, many livid green corals, and the well-known Planarian worm called Convoluta. In all these cases the partner algæ utilise the carbon dioxide and nitrogenous waste produced by the host-animal, which in turn gets oxygen and carbon compounds from its symbions. And it is always open to the dominant partner of the firm to digest his partners. There can be no doubt that this kind of symbiosis is profitable, for it is widespread, and its occurrence enables us to understand better the emptiness of the food-canals in many flourishing coral-colonies. At a lower level there is a case on record of a colony of thousands of green Amœbæ which lived for ten years in a glass vessel without a particle of solid food, the animal depending entirely on what its symbions produced.

Grades of Symbiosis

There is naturally considerable variety in the intensity of the symbiosis. It may be a casual or a constant partnership; it may be an advantage to life or absolutely indispensable. In the green Convoluta the egg is without any associated algæ, but the young larvæ must be infected if the development is to continue; the interdependence is very intimate. In the green Hydra the egg is infected before it is separated from the parent, but the symbions are not in this case indispensable. Many years ago Whitney made the neat experiment of keeping a green Hydra for a fortnight in a 5 per cent. glycerine solution at 20° centigrade, with the result that the minute green algæ, which live inside the inner layer or endoderm cells all died. The Hydra thus became wan white and so it remained for over two months without a trace of green. It fed in the usual Hydra fashion on small animals, and it budded in the normal way. In this case, therefore, the symbiosis is evidently not obligatory, though it is doubtless advantageous.

It is difficult to draw a firm line between symbiosis and parasitism, especially when we understand that there is a tendency to work out a live-and-let-live compromise between parasite and host. An intruding parasite, like the fungus in the heather, may be tamed into a symbion. On the other hand, a symbion may perhaps sink into a parasite. In the food-canal of animals there is often an occurrence of useful bacteria and infusorians which facilitate the digestive processes, and although these are not inside the tissues it would be pedantic to exclude them from the ranks of symbions. Similarly, yeast-cells of various kinds are often found in the food-canal of insects and seem to be of value in operating upon and improving the food-material. When the pomace-fly, Drosophila, is feeding on fermenting fruit, it *must* have yeasts to help it, and this kind of partnership is of wide occurrence.

A quaint heresy has been started more than once in the last few years that all living creatures except bacteria illustrate symbiosis, the idea being that certain formed bodies in the microcosm of the cell are tamed bacteria which have come to be indissolubly bound up in the bundle of life with their bearers. There is no good case to be made for the heresy, but it is interesting as an exaggeration of the truth that there is a widespread tendency in the realm of organisms to link lives together, to establish inter-relations.

XXVIII

ODDITIES OF DIET

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In the matter of food we often show absurd prejudices. We smile at the Chinese who make a rather costly soup out of the nests of the Sea-Swift (Collocalia), but as the whitish nests are made of consolidated salivary juice from the bird's mouth the soup is probably very digestible. As to taste, that is a matter of opinion. The Japanese eat dried jellyfishes, but what could make a more delicate sandwich? And as to sea-cucumbers, the *bêche-de-mer* so much appreciated in the East, they are certainly as inviting as the sausages which they resemble. Once a year the waters around Samoa are thick with the wriggling headless bodies of Palolo-worms that have swarmed out of the coral-reefs. The sea is like vermicelli soup, and the natives catch the worms in basketfuls and have a great feast. But this is just as reasonable as enjoying caviare, which consists of the roe or eggs of the sturgeon. We shrug our shoulders at people who eat big grubs or locusts, or who nibble at the raw arm of a cuttlefish as we eat celery, but it is mainly prejudice. And we must also remember what a treat anything fleshy must be to people who are forced to live all the year round on mealy food. It is sheer prejudice to despise the toothsome periwinkle—"the poor man's oyster," as it has been called; and it is absurd to turn up our nose at the palatable snail and the delicate muscle of the frog. But we wish to think of oddities of diet in animals, not in men.

Peculiar Feeding Habits

In South Africa those who know where to hide sometimes see the Aard-Vark, an antediluvian animal, belonging to the sloth-anteater order of Edentates. It rests well concealed during the day and comes out at dusk to hunt for food. It has a long, somewhat piggish, snout and a worm-like tongue, which is whipped out and in with great rapidity. The Aard-Vark is particularly fond of burgling the earthen fortresses of the termites or white ants. When it has made a hole in the wall it sticks in its snout and its sticky tongue works like lightning, out and in, out and in, until the big creature has had enough. It is a strange way of feeding. The Common Cuckoo is particularly fond of hairy caterpillars, which most insectivorous birds leave severely alone, for the hairs are often very irritating. But here is one of the many ways in which the cuckoo breaks through bird rules. It eats so many woolly caterpillars that the hairs form a thick feltwork inside its stomach. There is a touch of the unique about this.

If you stir up a big ant hill in the woods—once in a season will be enough—you detect a strong odour. That is formic acid (Formica, an ant), and all ants, whether they sting or not, secrete formic acid—corrosive and unpalatable. Because of this the majority of birds leave ants alone, except as an occasional mustard to their food, but there are some woodpeckers that delight in them. Over a thousand ants have been taken from the crop of a woodpecker, which means a considerable quantity of formic acid. Again, we get the impression that some animals seek out oddities of diet. There is often an unexpectedness about the food!

Clothes-Moths

Many people are familiar with clothes-moths, minute greyish creatures that sometimes fly out when we disturb

clothes that have been left hanging for a long time. But very few people have thought about these insects, for calling them bad names is not thinking. They do great damage to clothes and furs, and they are very exasperating in their destructiveness. It is easier to keep them out than to get them out when they have got in. One way is to use something like naphthalene-balls, for the moths are repelled by the strong odour; and the trouble begins when the female moth lays its eggs in the muff or woollen stuff. Another way is to wrap the fur up in tissue paper, for the moth cannot break through. We have known of precious skins remaining untouched for many years simply because there was no hole in the tissue-paper wrappings.

Out of the eggs come very minute and very slender larvæ, and they devour the hairs of the fur or of the woollen fabric, and it is an interesting point that they will not touch vegetable hairs or fibres. Thus they have no use for cotton-wool or paper. The larva feeds and grows and moults, and when colder weather comes it spins some hairs together into a tiny tube, and lies quiet, undergoing a slow change into a moth. There is nothing very remarkable in all this—except in the sense that everything is remarkable—but what makes us rub our eyes is the food. For what is hair made of but horn (or keratin), and no more indigestible stuff could be imagined. A man may swallow a dozen shrimps "holus bolus," but, so far as we know, he makes nothing whatever of the husks of chitin. They are almost quite indigestible, and the same must be said of horn. The answer to the puzzle is probably that the larva of the clothes-moth has partner micro-organisms (yeasts) in its food-canal which enable it to deal with the horny hair.

If we understand the case of the clothes-moth, we cannot be surprised that there are special larvæ that feed on the horns and hoofs of dead animals. There is also a whole order of somewhat lice-like insects (Mallophaga)

which live as parasites on the feathers of birds and hairs of mammals, especially while these are still young. As long as the feathers and hairs are growing the insects will get some living matter to eke out the horn, and it must be admitted that some of the insects in question suck blood like true lice.

Wax-Moths

Another strange case, well known to bee-keepers, is that of the larvæ of the Wax-Moth. They make silk-lined tunnels through the comb and do much damage. What particularly interests us at present is that these larvæ eat wax—a non-nitrogenous carbon compound that no other creature can make any use of. It seems that the larvæ of the Wax-Moths must have wax to eat, but as no animal can live without nitrogenous supplies this cannot be their sole food. They pick up unconsidered trifles in the form of pollen grains and the dead bodies of bee-grubs; and so they manage to eke out a meagre subsistence.

Sea-Cucumbers and Earthworms

As in the last case, some ways of feeding are not so strange as they appear at first sight. A sea-cucumber is a sausage-shaped animal with a wreath of branched tentacles around the mouth. In many cases the sea-cucumber feeds in a quaint way. It immerses one of its tentacles in the adjacent mud and then plunges it into its mouth, as a boy might deal with his treacle-covered fingers. Then the sea-cucumber does the same with another tentacle, and so on all round. But the creature is not eating mud; it is utilising the minute organisms and organic particles which the mud contains. And so, of course, with the earthworms, which eat their way through the soil. That in itself is of no use for food, but it contains

rotting fragments of plants which the earthworms digest, while the finely ground soil is passed out in the form of "castings," so familiar on lawns and putting-greens. The same is true of many seashore animals that eat sand, such as the Fisherman's Lobworm; it is not the sand that counts, but the multitude of minute creatures or, it may be, "crumbs" which the sand includes.

Necessity and Invention

What does it all mean—this feeding on termites, hairy caterpillars, ants, hair, horn, wax, mud, and so forth? We may be sure that it is not caprice. It is an indication of the stringency of the struggle for existence, and of the tendency that all hard-pressed living creatures have to take advantage of any vacant niche of opportunity. If there is a corner that other competitors are not occupying, it will soon be possessed. If there is a kind of food that other competitors are disdaining, it will soon be appreciated. It is by specialising in habitats and diets that so many different kinds of creatures can get on together in the same surroundings. So these oddities of diet are not what might be called "curiosities," they have a deep significance. They illustrate the biological insight of the old tag: "Jack Sprat could eat no fat; his wife could eat no lean." That was how they managed to get on at all; and it is the same in Wild Nature. This sheds a new light on the old saying: Nature abhors a vacuum. The river of life is always in flood, filling every vacant corner. The great majority of animals die young; can we wonder that all sorts of food-materials are tried? Necessity is the mother of invention, and perhaps we should not forget the father—Curiosity.

The last remark applies particularly to cases among the higher animals, where a change of diet is in progress, or where some novel item is included in the menu. Thus

there seems no doubt that during the present century the Herring Gull in Scotland has become more vegetarian than it used to be. It is naturally a fish-eater; but it is taking more and more to the harvest fields, and it has become very expert in gouging out turnips. In the same way the New Zealand Parrot or Kea, naturally a fruitarian, has learned, in a comparatively short time, to kill sheep for the sake of the fat about the kidneys. In the same way an individual cat may become very fond of green meat, including cabbages. Perhaps the last case is pathological, but all these idiosyncrasies have their interest. They illustrate variations in habit, and some of them may be among the raw materials of future evolution. But to expect the lion to make a habit of eating grass like the lamb seems to the zoologist somewhat optimistic.

XXIX

PLANTS LIVING IN INSECTS

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EVERY year brings increased knowledge of the Web of Life, and one of the recent revelations has been the extent to which plants live inside insects in an intimate partnership or symbiosis. Just as a lichen on the wall is a double plant—an Alga and a Fungus living together with profit to both, so many an insect is a mutual benefit society!

Bacteria of Cockroach

In the common cockroach and in all its relatives that have been examined there are bacteria living inside the cells of the reserve tissue known as the fatty body. These bacteria are not harmful but friendly, and they pass on from one generation to another. They enter the egg before it leaves the mother-insect; they multiply within the embryo; they sojourn for a short time in the developing food-canal, and then they find their headquarters in the fatty body. In one of the common wood-eating ants there is a similar partnership. The cells lining the digestive part of the food-canal always contain the threads of a slime-fungus, sometimes like an extremely minute ball of twine; and in this case also there is very early infection of the egg cell and a multiplication within the embryo. It must be noted that we have to do not with a general distribution of the fungus throughout the insect, but with a localised occurrence in the wall of the food-canal.

Yeasts of Death-Watch

Most of us are familiar with "death-watches" which make tapping noises in the wainscot. The sounds are made by the male thumping his head against the wood as a signal to his desired mate; so they speak of love, not of death! These death-watches remain young for a long time and the larvæ bore in wood and other dry materials, including books. One kind is the "biscuit weevil," too well known to sailors, and it is a quite extraordinary illustration of the kind of symbiosis or living together that we are describing. At the beginning of the digestive part of the food-canal—we envy the man who can dissect a biscuit weevil—there are two minute pouches, and these are crammed with yeast-plants. The insect has an internal brewery; but whether the yeasts ferment the wood, or whether they capture nitrogen in some way, is uncertain.

Microscopic examination showed Professor Buchner that there were no yeast-plants in the eggs, yet the young grubs always have them. The solution of this puzzle is almost incredible. Associated with the egg-laying apparatus in the female beetle there are two minute reservoirs opening to the exterior, and these are full of yeast-plants. When an egg is laid some yeast-plants are expelled, and they adhere to the shell, which is rough all over. When the beetle-grub that develops from the egg is ready to hatch out, it nibbles at the shell, and thus its food-canal is stocked with yeast-plants. Only a few need be swallowed, for yeast multiplies with great rapidity. A little leaven goes a long way with these death-watches. The whole story is almost eerie. It is one of the very few cases in which the partner-plant is not handed on inside the egg.

Utilising Unpromising Food

One of the dangers of unskilled vegetarianism is having to eat too much cellulose, for man does not seem to have any

digestive ferment for dealing with that material, which forms the cell-walls in all ordinary plants. What happens is that bacteria in the food-canal attack the cellulose, say in the lettuce, the cabbage, the celery we eat, and change it into sugars. So the unskilled vegetarian is apt to ask too much of his bacteria, which, moreover, are apt to carry their work of fermentation far beyond the limits of utility. We are not forgetting that sheep and cattle live very largely on grass, and yet they are also without cellulose-digesting ferments. But they have got various contrivances which man has not got, such as the paunch which contains a huge army of bacteria. This apparent digression was necessary in order to enable us to understand those caterpillars that live on most indigestible materials. We have already taken the case of clothes-moths. We do not suppose that the adults require much if anything to eat, but the tiny caterpillars require a great deal, for they have to grow. Yet what do they feed on but hair, which is made of keratin or horn. It is difficult to think of anything more indigestible, and yet it is digested. They say that sheep can grow fat on blotting-paper; the larvæ of the clothes-moth thrive on wool. In both cases the required fermentation is brought about by bacteria in the food-canal. It will be noted that in these instances the partners live freely in the cavity of the food-canal, whereas in the cockroach and the death-watch they live inside certain cells.

Bacteria of Green-Flies

As long ago as 1858 Huxley described in green-flies or aphids a peculiar paired organ which he called a "pseudo-vitellus," because its contents looked yolk-like. But it was not till about ten years ago that the nature of this enigmatical organ was discovered. It consists of strands of cells which are packed with bacteria, bearing a very

close resemblance to the nitrogen-capturing bacteria that form tubercles on the roots of leguminous plants like peas and clovers. The organ is a sort of culture-ground for partner bacteria which probably capture nitrogen for the green-fly. In any case they are friendly, not hostile. These aphids are viviparous all through the summer months, and the fully-formed young creatures that leave the mother have already their stock of bacteria. The useful infection takes place in the early embryo. In autumn, however, the aphids are oviparous, and in this case the infection takes place through a minute aperture in the envelope of the egg. Besides aphids there are some other sap-sucking insects with partner plants, such as scale-insects and cochineal-insects and frog-hoppers; and Buchner has described several Cicadas in which there are actually two kinds of symbions always present in the same insects, sometimes independently and sometimes in very close combination. Wheels within wheels again!

The Gnat's Bite

The gullet of the common gnat bears three minute pouches, and these contain gas-producing fungi which in certain circumstances become very numerous. Thus if the gnat is fed on fruit-juice, they multiply greatly and they may kill the insect with their gas-production. According to Schaudinn and others, some of these fungi get into man's skin when the gnat or mosquito inserts its stilets. It may be that the gas, probably carbonic acid gas, hinders the coagulation of the victim's blood, while a ferment also produced by the fungi increases the blood-pressure and irritates the skin. The typical irritation can be produced apart from any bite, by rubbing the gullet sacks on man's scratched skin!

In the seventeenth century two of the pioneer microscopists, Hooke and Swammerdam, described in the louse

a peculiar little organ, the "stomach-disc." Two or three years ago the meaning of the organ was discovered by Sikora and Buchner. It is one of these incubation-organs; it is a mass of intracellular rod-like fungi. There are special arrangements for infecting the ova, so that every louse has its partners from birth. The probability is that the fungi produce a ferment which passes into the skin of the victim and causes local increase of blood-pressure, thus facilitating suction. The partnership has been demonstrated in several kinds of lice, and the bed-bug shows it too.

We have taken these examples from Professor Buchner's remarkable book, *Tier und Pflanze in intrazellularer Symbiose* (1921), where scores of others may be found. It will be seen that the linkage occurs in many different kinds of insects; that except in two cases it is established in the egg to begin with by ante-natal infection; that it finds realisation in various parts of the insect's body; that it is turned to various uses; and that the symbions are of different kinds—bacteria, yeast-plants, slime-fungi, and other fungi. We wonder how the varied partnerships arose, whether the insects have been able to domesticate and tame what were originally intruders. We wonder also to what extent the partner-plants have changed the ways of the insects.

XXX

THE CAT AND THE MOUSE

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MANY common sights are very puzzling, as the wise man said long ago in regard to the way of the vulture in the air, the way of the snake on the rock, and some other things. One of these puzzling sights is the way of a cat with a mouse. In many cases, as everyone knows, it does not kill its victim outright, but allows it to escape and catches it again. Many times over it repeats the performance. What is the interpretation?

Theories of the Cat's Behaviour

Some people see in the cat's behaviour a flagrant instance of what they call "the cruelty of nature." In most cases the violent death that one animal meets at the hands of another is almost instantaneous; we once timed a golden eagle killing another bird, and the episode was over in less than thirty seconds. It seems rather hypocritical as well as anthropomorphic to call this cruel. But the case of the cat and the mouse is different. The cat prolongs the process; it looks as if it teased its dazed victim; and Romanes, who was one of the pioneers of comparative psychology, committed himself to the view that the cat shows a delight in torture. But this is too sophisticated for a cat; it needs a man to have so barbarous a gratification. Others have suggested that the cat does it to whet its hunger, and they interpret the fact that the cat often leaves the mouse uneaten as due to a failure of the psy-

chical appetissant. Here it may be noted that cats are keen sportsmen, and will kill creatures which they never eat. Thus a cat will kill a shrew, but the odoriferous gland along the side of the shrew seems to be repellent, and we never heard of a shrew being eaten by a cat. But no one could expect an instinctive impulse to discriminate in any hard and fast way between catching a mouse and catching a shrew.

A Form of Play

Another suggestion is that the cat teases the mouse to improve its flavour, but this, again, is grotesquely anthropomorphic. It is reading the man into the beast. The true interpretation, which does not strain our credulity, is this—that the cat is playing. There are many animals which play when they are young, and it is hardly too much to suggest that their youth is prolonged so that they may play. For the biological interpretation of play is that it affords an apprenticeship to the business of life before responsibilities become serious, that it is a time when instinctive behaviour is often modified by intelligent learning, and that it gives elbow-room for testing idiosyncrasies and new departures. As Groos has so well shown, play is not a trivial thing, but essential; it is a vital part of animal education. The play of lambs, kids, puppies, kittens, and many other mammals is familiar, and one of the forms of play is the sham-hunt. Everyone knows how the kitten chases the ball of worsted or the wind-blown leaf, catches it, lets it go, catches it again. The moving object pulls the trigger of the hunting impulse, and even when the kitten is very tired it cannot resist one more hunt when you roll the ball past its nose.

Brehm prettily describes the familiar sight. "The playfulness of kittens is marked when they are very young, and the mother does everything to encourage it. She

becomes a child with her children from love of them, just as a human mother forgets her cares in play with her little ones. The cat sits surrounded by her family and slowly moves her tail, the indicator of her moods. The kittens hardly grasp its language as yet, but they are excited by the motion, their eyes take on expression and they prick up their ears." The play has begun, and it is interesting to watch it becoming more complex, for by and by the kitten will lie in wait for the moving ball of worsted and will spring upon it like a tiger.

But not only does the mother-cat share in her kitten's play, she may occasionally relapse into a game when she is by herself; and this is the interpretation of the cat's way with a mouse—she has returned to her juvenile playfulness. This persistence of play into adult years is seen in some other mammals; it is beautifully illustrated by otters, and we have seen even the sedate sheep forgetting themselves!

The Mousing Instinct

Some experiments made a good many years ago by Mr. C. S. Berry tended to show that cats learned by imitation to kill mice. An unprejudiced uninitiated cat would allow a mouse to perch upon its back. The cat's interest was not aroused till the mouse ran. But subsequent experiments by R. M. Yerkes and D. Bloomfield showed conclusively that young kittens react to mice in a way that differs radically from their reaction to a moving ball. The killing instinct appears suddenly, usually during the second month. In a moment the playful kitten is transformed into a beast of prey. It bristles up its hair; it switches its tail; it may hiss, spit, or growl; it unsheathes and sheathes its claws; it catches the mouse by the back of the neck. The movement of the mouse seems suddenly to liberate an inborn capacity, a ready-made trick, an

instinct; but the odour of the mouse counts and counts increasingly. If the kitten grows up unexperienced, the instinct seems to become more and more difficult to evoke; but the young kitten can kill in the fit and proper way without either experience or imitation. At first the killing tends to be immediate; "playing with the mouse" comes later.

"Instinct" is one of the most abused of words. People speak of the political "instinct," the "herd-instinct," the "sex-instinct," the predatory "instinct," the religious "instinct," the feminine "instinct," the physician's "instinct," and so on till one is tired. Yet the zoologists have come to general agreement as to the meaning of "instinctive behaviour"—the adjective is safer than the noun; and this meaning is well illustrated by what has been said of kittens killing mice. Instinctive behaviour is the expression of hereditarily pre-established linkages between certain nerve-cells and certain muscle-cells. When the button is pressed the performance comes off, one act giving the cue, so to speak, to the next act. The nerve-cells concerned are (1) the receptors (or scout-cells), (2) the adjustors (or G. H. Q. cells), which receive the tidings and pass them on, and (3) the motor or efferent nerve-cells (say executive-officer cells), which see that the muscles (the so-called "common soldiers") obey orders. Instinctive actions do not require to be learned, though they may be perfected by practice. Unlike intelligent actions, they do not require much attention from the G. H. Q. or adjustor cells; yet it often happens in birds and mammals, and occasionally in ants and bees, that G. H. Q. intelligence or "perceptual inference" intervenes at a critical moment. We do not believe that instinctive behaviour is without its psychical side; it has its cognitive and conative aspects in the inner life. To say the same thing over again, it is suffused with awareness and backed by endeavour.

XXXI

THE DANCING MOUSE

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ALTHOUGH the origin of this fascinating little animal is uncertain, the probability is that it arose in China some centuries ago as a freak or mutation from the common mouse stock. It is distinguished especially by its habit of waltzing round in circles of varying radius and of whirling round with great rapidity. Perhaps in the strict sense it does not *dance*, but it is difficult to define nowadays what the term dancing includes. It is an interesting fact that variations like incipient dancing occasionally crop up among ordinary mice. In all likelihood the dancing mouse would have gone to the wall in wild nature, for it is a freak inclining to the pathological, but it came under the ægis of Japanese breeders, who took care of it and subjected it to artificial selection. It is now a well-established artificial race which breeds true. Its protection is due to its whimsical ways, but whereas those brought to America and Europe are generally allowed to disport themselves in spacious cages where they have plenty of room for displaying their "circus-movements," those in the Far East are kept for the most part in confined boxes where they put mechanical devices into action by running round inside a drum-like wheel.

Movements

The scientific interest of the dancing mouse has been explained by Professor R. M. Yerkes in a monograph

published in 1907 and in a number of subsequent papers, and what we have to say is dependent on these masterly investigations, for our personal experience of the charming creature is not worth talking about.

Let us begin with the dance movements. Before the young mouse is able to leave the nest it begins to move in circles and to raise its head in a quick jerky way. At the age of three weeks it dances vigorously. It is extremely restless, "incessantly active when not washing itself, eating, or sleeping"; it is continually lifting its head and sniffing with the nose pointed upwards; it whirls round like a top with all the feet close together underneath the body, or it runs rapidly round in circles of two to twelve inches in diameter with the feet spread widely, or it moves in figure-eight and zigzag fashion. Two mice often dance together, sometimes moving in the same direction, or one clockwise and the other anti-clockwise. There are left, right, and mixed whirlers, the first in the majority. They usually rest for most of the day, emerging towards dusk, and dancing with varying intensity for some hours. Zoth counted seventy-nine whirls without an instant's interruption, and Yerkes counted as many as one hundred and ten whirls. This indicates great power of endurance, specialised in a particular direction.

Peculiarities

We wonder that the whirlers are not overtaken with extreme dizziness, but this is one of the peculiarities. If a normal common mouse is rotated in a rapidly moving cyclostat it falls into convulsions, but the dancing mouse does not seem to mind much, if at all. It is exempt from the dizziness usually produced by rapid rotation, and also from visual dizziness when placed on an elevated surface. On the other hand, the dancing mouse shows more or less deficiency in the power of balancing (equilibration) and of

placing its body in a particular position (orientation). Furthermore, it is partially or totally deaf.

These peculiarities led investigators long ago (1899) to inquire into the structure of the ear in the dancing mouse, and several of them discovered anatomical anomalies which they sought to associate with the animal's unusual behaviour. Thus it was confidently stated that of the three semicircular canals around the ear, which have to do with balancing in ourselves, only one attained development in the dancing mouse. Another anomaly in the cochlea of the ear was described as accounting for the deafness. Unfortunately, however, the structure of the ear is an exceedingly difficult subject, and subsequent investigators have not confirmed what their predecessors believed they had discovered. There must be some structural basis for the peculiarities of behaviour—the bizarre movements, the defective balancing power, the nervous jerking of the head, the insensitiveness to sounds. But it is not at present, we understand, possible to state what the correlated peculiarities of structure are, either in the semicircular canals, or in the cochlea, or in other parts of the ear, or in the brain, or in the rest of the nervous system. This is a very disappointing conclusion.

Many animals have been labelled deaf because they did not respond in any way to certain loud noises. But the possible fallacy here is that the animal may fail to respond, not because it does not hear, but because it is not interested. Therefore Professor Yerkes tried the adult dancers with a great variety of sounds—clapping the hands, whistling, shouting, ringing a bell, causing another mouse to squeak, sounds to which ordinary mice respond. Working for three years with more than a hundred individuals, he never got any reaction that could be referred with any fair degree of certainty to an auditory stimulus. The adult is totally deaf. But, curiously enough, Professor Yerkes's work also showed that the young dancer

sometimes hears sounds *for a few days* during the third week of its life. One's curiosity is heightened by the fact that shortly before the brief period of auditory sensitiveness the young dancer becomes extremely excitable and pugnacious.

Experiments

By ingenious experiments, which rewarded the animals when they chose correctly and punished them mildly when they failed, Professor Yerkes was able to prove that the dancing mice can discriminate between different degrees of brightness, whether the light was reflected from cardboards of different kinds or was transmitted through ground glass. One mouse that he worked with for several weeks gradually improved in discriminating power until she was able to distinguish between two boxes whose difference in illumination was less than one-tenth that of the brighter box. "At the beginning of the experiments a difference of one-half did not enable her to choose as certainly as did a difference of one-tenth after she had chosen several hundred times. Evidently we are prone to underestimate the educability of our animal subjects." Patient experiments, a model of scientific caution and precision, led Professor Yerkes to the conclusion that true colour-vision, if it exists at all, is extremely poor in the dancing mouse; and it is interesting to be able to associate with this the fact that while the retina has the usual rod-like cells of the typical mammalian retina, it has nothing closely similar to the cones, which are believed to have to do with colour-vision.

Educability

The dancer is quick and neat in its restless movements, but careful watching shows that two sometimes collide,

and that only those doors with which the animal is familiar are entered skilfully. Experiments prove that the form of objects is not clearly perceived, but that movements are; and the general conclusion is that sight is not of very great importance in the daily life of the creature. Touch and smell probably count for much, but habit for more still. The dancer learns to find its way quickly out of a maze, and when it has learned the trick it can follow the path apart from any trail and in the dark. In all probability a motor habit has been enregistered which can work without any immediate guidance from the senses.

Of great interest are the experiments by which Professor Yerkes was able to prove the educability of the dancing mouse. Beside the cage, to take a simple case, he placed a wooden box, from which a ladder of wire netting led home. "A dancer when taken from the next-box and placed in the wooden box could return to its cage and thus find warmth, food, and company by climbing the ladder." The results varied, showing marked individual differences in intelligence. The mouse called No. 1,000 learned to climb quickly, and largely by his own initiative. But those called No. 2 and No. 6 learned only by tuition, being put through the required act by Professor Yerkes. Some could not get out at all. One of these, called No. 5, was placed along with No. 1,000 in the box, but failed to profit in the least by repeated trips which No. 1,000 made for her benefit day after day.

Unlike some other animals, the dancing mouse does not seem to profit by what its neighbours do. Imitation counts for almost nothing. By using the labyrinth method, it was found possible to measure the varying rapidity with which a habit can be formed and to test the durability of the habit when it has been acquired. We have not been able to do more than hint at the heights and depths of the inquiry into the peculiarities of the dancing mouse, but

we have perhaps said enough to show that it has already justified its existence by affording a most excellent subject for the scientific study of animal behaviour. It is no *corpus vile!*

XXXII

BIOLOGICAL DICHOTOMIES

BIOLOGICAL DICHOTOMIES

THROUGHOUT animate Nature we see bifurcations, many of which certainly depend on the see-saw of protoplasmic metabolism, as that again depends on some deeper dichotomy till we get down, it may be, to the difference between positive and negative charges of electricity. In every living body there is building-up and breaking-down, synthesis and analysis, winding-up and running-down, anabolism and katabolism, repair and waste, assimilation and disassimilation, income and expenditure, and so on—for such is the fundamental antithesis of life from the chemical and physical, as well as from the common-sense point of view. A living creature, however simple, implies keeping a balance between the two sides and being a going concern, enduring for a longer or shorter time. But the fulfilment of this primal condition leaves room for many alternatives or organic dichotomies.

Plants and Animals

Very far back in the history of living creatures, antecedent to the definite cleavage between plants and animals, there was a divergence between those organisms that fed at a low chemical level—on the primary constituents of the atmosphere, water, and its dissolved salts, and those organisms which could not utilize anything but complex nutriment previously manufactured. This was the primary cleavage between the peaceful and the predatory,

between feeding-low and feeding-high, between savers and spenders; and it expressed a dichotomy between the relatively more anabolic and the relatively more katabolic. An incalculably important step was made when plants acquired the green pigment chlorophyll, which made it possible for them to utilise more readily the energy of sunlight in their photo-synthetic activity which remains mysterious. Thus was established the deep cleavage between plants and animals, which differ from one another as munition works from active batteries. Green plants have extraordinarily preponderant anabolism; they make and store abundance of explosives which animals may eventually utilise.

Saving and Spending

Now, all through the evolution of animals, we can discern the same forking of the ways; we see it in the contrast between a sluggish Sporozoon, such as the malaria parasite, and an intensely active Infusorian, such as the luminescent Noctiluca of all the seven seas; between the sedentary corals in their thick-walled castles of indolence and the free-swimming, aggressive Portuguese Men-of-War; between the fixed barnacle and the frolicsome shrimp, the limpet and the sea-butterfly, the ascidian and the salp, the tortoise and the eagle, the ground-sloth and the aërial bat. Of course all sorts of secondary adaptations have been in each case super-added, but to begin with there has been, as it were, a choice between two possible modes of life: the relatively anabolic and the relatively katabolic, the more conservative and the more adventurous, the saving and the spending habit.

Female and Male

There has been recent experimental corroboration of the thesis of *The Evolution of Sex* (Geddes and Thomson, 1889)

that the sex-divergence is an illustration of a widespread organismal dichotomy, that the female is an organism in which the ratio of anabolism to katabolism is greater than the corresponding ratio in the male. In other words, the sexes differ fundamentally in the rate and rhythm and routine of their metabolism, the females being the relatively more anabolic. In pigeons there appear to be two different kinds of eggs, usually produced in approximately equal numbers, but in this respect modifiable by conditions of age, season, and so forth. Now the eggs which have adopted a more anabolic régime, storing more abundant and valuable reserve products, develop into females, and the others into males. There are many indirect confirmations of this physiological theory of sex, which is not inconsistent with the view that the immediate index and trigger-puller of one sex or the other may be found in nuclear peculiarities (sex-chromosomes) in the germ-cells. But our immediate point is simply that the sex-antithesis may be but a special case of a still more widespread dichotomy.

Tender and Tough

Corresponding to the dichotomy between plants and animals, there is among animals, as regards diet, an analogous contrast between the soft-mouthed and the hard-mouthed, the tender and the tough. The soft-mouthed animals feed on the whole on microscopic organisms, organic débris, and fine detritus, good examples being sponges, some corals, sea-cucumbers, feather-stars, earthworms and lugworms, acorn-shells and barnacles, oysters and other bivalves, ascidians, lancelets, and a few fishes. The hard-mouthed animals are predatory, and have something in the way of jaws, good examples being sea-urchins, Nereids, crabs, snails, and octopuses, most fishes, and all higher animals. And just as we thus divide animals into those that feed at a low level and those that

feed at a high level, so an analogous parting of the ways splits the latter into the pacific vegetarians and the predatory carnivores.

Many-Celled and Single-Celled

Another deep cleavage was between the unicellular and the multicellular mode of being, which Agassiz called the greatest gulf in organic Nature. The emphasis must not be laid on the difference in size, for size does not mean very much, and it is easy to find a single-celled (or non-cellular) animal far bigger than a Rotifer with a thousand cells, far bigger than a minute insect (with thousands of cells) which lands like a comma on our page as we read. Nor should the emphasis be laid on the difference in complexity, for while it may be true in a general way that unicellular animals are simple compared with multicellulars (Metazoa) from sponges to man, it is easy to find an Infusorian of extraordinary complexity. Think of Bellerophon, for instance, with its row of projecting turrets on each side, into which explosive capsules pass and are fired off when occasion requires! Every one of these minute animalcules is physiologically complete in itself; the life-histories are often so intricate that we find it difficult to remember the succession of chapters; the results of their architectural activity, whether with lime or flint produced inside of them, or with extraneous particles collected from outside, are as beautiful as they are puzzling; and it is no figure of speech to talk of their "mind." We cannot very well say "higher" or "lower"; they are on a different evolutionary tack; they illustrate a deep dichotomy, the interest of which is enhanced by their remarkable evasion of "natural death." It may be that the difference between unicellulars and multicellulars, between organisms without a "body" and those with one, is an architectural, rather than a physiological, dichotomy;

but it is probable that the possibility of having a "body" with cells, tissues, and (eventually) organs, depended on a relatively anabolic period during which reserves were accumulated and dividing cells remained coherent instead of going apart in individualistic independence.

Radial and Bilateral

Another eventful parting of the ways was that which separated the bilateral from the radial animals. The radial symmetry of jellyfishes, polyps, and the like, which have no right and left sides, no definite head and tail, is well suited for easy-going, sedentary, or drifting life. But bilateral symmetry, beginning among multicellulars with "worms," implies right and left, head and tail, and was better suited for a more vigorous life which commands its course, pursuing prey, avoiding enemies, and chasing mates. The establishment of bilateral symmetry was the beginning of our knowing our right hand from our left; it led to the establishment of head-brains and to a cephalisation which only needed to be begun to succeed like success. The dichotomy between radial and bilateral animals was again architectural rather than physiological; but, while there are many notable exceptions, the majority of the radially symmetrical are sluggish, vegetative, and feeding low, while the majority of the bilaterally symmetrical are active, masterful, and feeding high. It is interesting to notice that the intensely active and luminescent Ctenophores, like "sea-gooseberries" and "Venus's girdle," which are bipolar and incipiently bilateral, are all carnivorous. Some zoologists believe that it is among these Ctenophores that the origin of bilateral "worms" is to be sought.

Little-Brains and Big-Brains—and Other Contrasts

As we have seen, there are dichotomies which echo the primary contrast between relatively preponderant anab-

olism and relatively predominant katabolism, and there are others which imply the introduction of some new idea or principle. Among the latter we may further mention the divergence between "the little-brain type," as Sir Ray Lankester calls it, rich in instinctive capacities but slow to learn, reaching its climax in ants, bees, and wasps, and "the big-brain type," with a meagre endowment of instincts, but eminently educable, finding its climax in mammals and man. There is the contrast between "cold-blooded" animals, whose temperature approximates to that of the surrounding world, and the "warm-blooded" birds and mammals, which remain of nearly constant temperature. There is also the momentous contrast between animals that lay eggs hatched outside of the body and those that have a more or less prolonged and intimate symbiosis between the unborn offspring and the mother, recalling the relation of seed to parent-plant, and evidently pointing to anabolic reserves on the maternal side. We must refrain from trying to follow the biological dichotomies into human life, where we see them in the contrast between the excitable and the phlegmatic, the sanguine and the placid, the adventurous and the cautious, William James's "tender" and "tough," which have, of course, to be correlated with conditions of blood-pressure, internal secretion, and metabolic routine. But one final suggestion we must be permitted. The occurrence of dichotomies is characteristic of animate Nature, and many human features, such as having two hands, two cerebral hemispheres, two eyes, two ears, and so on, probably incline us to a bilateral logic. Our dilemmas are two-horned; our answers are yea or nay. Experience teaches, however, the frequent validity of a via media, of compromise of the truth between two extremes. And, looking back over animate Nature, revising our impressions, we see that apparent dichotomies are often less absolute than they seem. There are many organisms that balance income

and expenditure, closely and subtly, there are intermediates between plants and animals, there are intergrades between the tough-mouthed and the tender-mouthed, instinct and intelligence are often subtly mingled, radial and bilateral do not exhaust the possibilities, many creatures are not wholly male or wholly female. As often as not the path of life shows trifurcation, not dichotomy.

XXXIII

MANY INVENTIONS

MANY INVENTIONS

THERE is a quality of insurgence in living creatures that is often startling. It is true that some seek the line of least resistance, and drift into a parasitic or a saprophytic life of ease, but that is not characteristic. The majority show fight—the will to live, and to live in a particular way, which is oftener against the stream than with it. The insurgence is expressed in prolific multiplication; the river of life is always threatening to overflow its banks and it often does so. One of the British starfishes has two hundred million eggs. The same quality is expressed in the multitude of distinct species—twenty-five thousand backboned animals, quarter of a million backboneless animals. It is shown in longevity, in the centenarian tortoise and parrot, or in the Big Tree that was cut down at the age of 2,425 years; in the conquest of space, the Arctic Tern occurring in the Antarctic circle; in the exploiting of inhospitable areas such as the dark abysses of the ocean; in the circumventing of the seasons, either actively like the swallows flying south or passively like the hibernating hedgehog; and in numberless other ways for which it is difficult to find the common denominator. Is it, as Spinoza hinted, that living creatures have a unique vital inertia, bound to express their nature in spite of discouragements, bound to persist in the line of their own being? In any case, what Goethe said is true, that it is characteristic of organisms to be always attempting the apparently impossible

and achieving it. The "Challenger" explorers showed that there is no "deep," even one that would engulf the whole of Mount Everest and show nothing, too deep for life.

Inventiveness

But there is another quality of organisms for which it is difficult to find a name—unless it be *inventiveness.* They have, indeed, sought out what look like inventions, but the familiar difficulty is that the capacity for these comes to be a racial possession at levels where we dare not suppose that we are dealing with deliberately thought-out devices. We shrink from the audacious generosity of naturalists who have spoken of the sagacity of the Venus's fly-trap and the shrewdness of the Bryony which binds itself to the hedgerow with a spring-anchor and rides the storm in safety; but how are we to describe the brainless starfish's life-saving surrender of a part, or the way in which a dismounted sea-anemone—no better endowed with brains—will attach itself to the leg of a hermit-crab and climb up on to the back of the shell, recovering a lost partnership? And if we say that the ploughboy recovers his seat intelligently while the sea-anemone does so reflexly, we have to face the difficulty of the origin of the highly profitable partnership between the crustacean and the cœlenterate. The hermit-crab who deliberately seeks a partner-anemone, and puts it on the back of his borrowed house, who adds a second and a third till he is masked, who removes his partners when he has to flit to a new house, who sometimes carries a partner on his great claw as if it were a weapon (and is it not richly provided with batteries of stinging cells?), has a fairly well-developed brain, and his behaviour may be suffused with an appreciative awareness of what he is doing. But the sea-anemone is on a much lower level, without nerve-

ganglia at all, and yet it is in some cases much more than acquiescent in regard to the partnership. Responsiveness to the touch of the hermit-crab may have come to be engrained in its constitution, but it is difficult to think clearly of its racial establishment.

Many Devices, Intelligent and Otherwise

In spite of some criticism, we adhere to the statement, which is well documented, that moles store earthworms near their headquarters in the autumn, and that they bite off their heads, with the result that the larder—a last resource when the frost grips deeply—remains fresh and yet cannot creep away. To what extent the mole is appreciatively aware of what looks like a device, who can say? The Sea-Swift, Collocalia, of the Far East, finds little material wherewith to build a nest on the walls of the caves; it makes one of consolidated saliva—the well-known edible bird's nest. The Greek eagle lifts the tortoise to a height, and drops it on the rocks below, with the result that the almost invulnerable carapace is broken open; rooks do the same with fresh-water mussels and gulls with sea-urchins. Now, when we are dealing with creatures of high degree, with finely developed brains, it is quite legitimate to make the hypothesis that they are intelligently appreciative of their agency—a hypothesis to be proved or disproved, perhaps, by carefully-arranged experiment. But when we pass to lower Vertebrates with poorly developed brains, the cloud of difficulty becomes more dense. What are we to say of the New Guinea fish, Kurtus, which finds no suitable or safe place for the deposition of the eggs, the outcome being that the male fastens them in a double bunch to a special bony hook on the top of his head, and carries them about till they hatch? What are we to say of the strange frog which Darwin found in Chili, where the male carries his small family in his internal

croaking sacs until they become miniatures of himself and escape? It is a quaint illustration of paternal care and of a self-denying ordinance, but is it intelligently inventive?

Instinctive Inventions

The difficulty increases when we pass to animals on a very different evolution-tack—that of insects and spiders. The tailor-ants, common in warm countries, make a shelter by drawing leaves together, and their co-operative hauling is admirable; their mandibles are their needles, if you like, but they have nothing to sew with; what does each do but take a larva in its mouth so that the silk secreted from the offspring serves as thread for the parents? A common harvesting ant of South Europe collects seeds of clover-like plants, lets them begin to sprout so that the tough envelopes are burst, exposes them in the sun so that the germination does not go too far, takes them back underground and chews them into dough, and finally makes this into little biscuits which are dried in the sun and stored for winter use. What a brilliant idea—and yet it cannot be that!—is suggested by the semi-domestication of greenflies by certain species of ants, and what shall we say of the slaves which others bluff into service? Many white ants or Termites grow mushrooms in extensive, specially constructed beds of chewed wood, and some of the true ants show a similar habit.

On wayside plants in early summer we see everywhere the frothy masses called cuckoo-spit, each made by a larval frog-hopper which whips a little sugary sap, a little ferment, and a little wax into a strange persistent foam, protective against enemies and against the heat of the sun, the creature literally saving its life by blowing soap-bubbles. Not far off, on a bare sandy patch, are the deep shafts sunk by the grubs of the beautiful green Tiger Beetle. The grub, with quaint somersault movements inside the

shaft, thrusts the loose earth with great force into the walls, and beats them smooth. Eventually it fixes itself near the top of the shaft so that the roof of its head forms a trap-door. When an ant or some other small insect settles down on this living lid, the grub suddenly explodes like a jack-in-the-box, hurling its victim violently against the hard upper edge of the shaft-wall. The sucked body is afterwards jerked out. The world is full of these inventions.

All Sorts of Devices

How are we to understand the behaviour of one of the Digger Wasps which lays its eggs in a sunk shaft, and provisions this with paralysed caterpillars? While the hunting and storing are in progress, the wasp shuts the mouth of the shaft after each visit, but does so in a rough-and-ready fashion. When the larder is full, however, it seals the entrance with earth and makes a neat job of it; nay, it takes a minute pebble in its jaws and beats the earth smooth. Who said animals could not use tools? It seems that using the pebble is not part of the instinctive routine, but is an individual touch, probably with more vivid awareness than is associated with the rest of the agency. But the difficulty is to think of the origin of either the routine or the finishing touch without postulating intelligence or, at least, some appreciation of significance.

The water spider, an aberrant member of a thoroughly terrestrial race, breathing dry air, has been led to explore and exploit the pools on the moorland. The female weaves a flat web on the bottom, mooring it by silk tent-ropes to the stones; she goes up to the surface, entangles air in her hair, comes down again, gets under the silk sheet, and presses off the quicksilver-like air-bubbles with her legs. She does this many times till the flat web is

buoyed up like a silver cupola; and in that dry diving-bell-like nest the eggs are laid and the young are hatched. The impossible has been achieved.

Spiders have no wings, but some small kinds are given to aërial migration! On a breezy morning, especially in autumn, they mount on posts and parapets and tall herbs, and, standing with their heads to the wind, give forth from their spinnerets multiple jets of liquid silk which harden instantaneously into threads of gossamer. When these are long enough, the wind tugs at them, and the spider lets go. It is borne with the help of its silken parachutes on the wings of the wind, disappearing like the boy in the Indian rope-trick. If the wind rises it can furl its sails, if it falls it can spread more; and when the threads have fulfilled their passive function and have sunk to the earth in thousands, we see a shower of gossamer.

Observant visitors to the Riviera are familiar with the shafts sunk by trap-door spiders on wayside banks. The lid, often about the size of a franc, is flush with the ground and usually exactly like its surroundings; it fits with precision and works on a silken hinge. The shaft is smoothly plastered within, and sometimes there is a side shaft, with a silken portière hanging over the entrance, into which the spider can retreat if an enemy gets into the shaft before she has shut the door. We say "she" because the shaft is for egg-laying and the mother spider's work. It is plain that there are many "ideas" here—the hinge, the concealment of the lid, the side-aisle, and so on. But in some kinds we see on the polished white internal surface of the lid three or four little holes close together, about the size of pin-pricks. What are these but holes for the spider's claws so that she can draw the door quickly and firmly after her? And they must be made while the cleverly manipulated clay is still soft. This comes near invention.

Thinking of the method of opening mussels by letting

them fall from a height, we can credit the fine brain of a rook with a fair share of intelligence; perhaps enough to take advantage of a method which a chance fall disclosed; perhaps enough to devise the method and to keep it up as a tradition. We must remember how the thrush smashes the snail shells on its anvil in the wood. But when we come to creatures of the little-brain type, whose behaviour is mainly on the instinctive level, we must cease to think of intelligently-thought-out inventions. We must think, it seems to us, of a continual individual experimentation with new tendencies and aptitudes, or with slight improvements on previously established aptitudes. Life has been a long-drawn-out game of "testing all things and holding fast that which is good." On our view, what happens at levels below what may be called intelligent learning and invention is briefly this: that in the germ-cells, which epitomise the past, novelties are of frequent occurrence, not "anyhow" novelties, but new departures more or less consistent with the past. These arise organically, of course, not by giving thought to the morrow, for that the germ-cells, at any rate, cannot do. But these germinal cards are put into the hands of the player, the embodied organism, mind-body and body-mind in one, and it is for the explicit organism to play them, to test them, and even to find the environing conditions where they are of most avail. It is in this way that the lower animals have profited by inborn inspirations never clearly thought out, and just as it may have taken a million years to fashion the feathers of birds, so it may have taken ten millions to endow the tribe of ants with their marvellous repertory of apparent inventions.

XXXIV

THE CALL OF THE SEA

THE CALL OF THE SEA

THE Loggerhead Turtles are open-sea reptiles of wide distribution, especially in the Atlantic. Two or three stray specimens have been captured on British coasts. They are carnivorous and of no commercial value, but they are very interesting because of the obedience of the young ones to the call of the sea. The adults are pelagic, as we have said, but the young turtles are hatched on shore, where the mothers have buried the eggs in the sand. About the month of August or a little earlier, the fully formed youngsters escape from the egg-shells and the sandy nest and make for the sea; and there is no clearer instance of an inborn obligation. It has been recently studied by a distinguished American naturalist, Professor G. H. Parker of Harvard, and his results are very interesting.

An Inborn Obligation

"To see a dozen of these newly hatched creatures, that have had no previous experience with the ocean, scramble toward it, notwithstanding that it may not be within the range of their vision, is a sight never to be forgotten. Any attempt on the part of an observer to check them in their course seems only to excite them to further effort which does not cease till they have reached the water. To the observer they seem to be drawn toward the sea by an

influence as mystical as it is impelling." This is the kind of problem that the biologist loves, to analyse the call of the sea.

The first thing Professor Parker did was to put a newly hatched Loggerhead at the centre of a paper board about a yard square and surrounded by a low wooden fence about six inches high. He pointed its head north, but it went west. He took another one and pointed its head south, but it went west—literally, of course, we mean. He took a third and pointed its head east, but it went west. He took a fourth and pointed its head west, and it went west. The experiment continued, with one turtle at a time, and almost without exception they went west. Why was that? The water and the later afternoon sun were both in the west.

The next step was to find out whether the sun or the water was the effective factor, and that was easily done by transporting the paper board and pen to the opposite shore of the narrow peninsula or Key in Florida where the experiments were made. Here the water was to the east while the sun not unnaturally remained in the west. The young Loggerheads all went east, which proved that their movements were related to the position of the water and not to the sun.

Not Guided by Sight, Hearing, or Smell of the Sea

"On my return from the ocean on the east side of the Key to the bay on the west side I stopped in a field about midway between the two bodies of water, and having set up the pen here with its floor horizontal, I proceeded to a third set of tests." The result was that when the turtles were treated as before they were not disposed to move much from the centre of the board, and that when they did move they were as likely to go in one direction as in another. They were not hearing the call of the sea.

Another fact soon emerged, that the young creatures are very responsive to the slope of the surface on which they move. They like going downhill, or, in more correct language, they are positively geotropic—at any rate after they escape from the shallow sand nest. So they will tend to go down the slope of the shore to the sea. Further experiments showed that they were not directed to the sea by the tang in the air, or by the humidity, or by the sound of the waves. When a shallow vessel of water was placed near the line of their seaward march they passed by without any deflection.

Towards the Free Horizon

But it was plain that there must be some directive influence, for when they were liberated in the pen in the darkness of night, they did not move towards the water as usual, but crept about indiscriminately. This suggested further experiments which led to the interesting conclusion that the newly hatched Loggerheads move away from any large mass that interrupts the horizon and move towards any considerable stretch of openness. From inside a tub, whence they could see only the overhead sky, they had no orientation. But from the top of an inverted tub, whence they could see all round, they directed their course for the sea. They did so, moreover, after moving round in a small tentative circle, as though testing the whole horizon and then following the line towards the greatest openness. They did not move towards a light in a dark room, but they are unmistakably influenced by a complex impression of open horizon as distinguished from a more interrupted horizon. Professor Parker insists that they respond to the details of their retinal images rather than to these images as wholes. Dr. Hooker, who made good experiments some years ago, concluded that the young Loggerheads move in the direction of blue sky, and

Professor Parker does not exclude the probability that they move toward blue areas rather than toward those of other colours. He has shown, however, that the creatures will find their way without either blue sky or blue water.

What then is our picture of the inborn susceptibilities of the newly hatched Loggerheads as they emerge in the daylight from the darkness or semi-darkness of the eggs and the sand? They are suddenly ushered into a world of which they have no experience and they exhibit an effective obedience to enregistered predispositions which are awakened by trigger-pulling stimuli. The first factor is that they will rather go down than up; and that works well. The second factor is that they move toward regions in which the horizon is open and clear, and away from those in which it is interrupted. This usually works well. And there may be a third influence that they tend to move towards blue, which may also work well.

If we were in the Loggerhead's place and in full possession of our faculties, we should sniff and listen, we should gaze all round and test the slope, and then would come profound reflection! But the Loggerhead does not reflect. Nor is it constitutionally bound to go toward the sea as a moth to the candle, or an earthworm to darkness. Its actions are inborn or instinctive reactions to particular stimuli, but they have not the obligatoriness of what are called tropisms. A very interesting point is that when a Loggerhead was started near some high shrubbery which intervened between it and the sea, it always moved away from the shrubbery and towards the open field. This was of course "wrong," but it shows that after all the call of the sea (for the Loggerhead) is the call of the open horizon! What is it for us?

XXXV

THE BEHAVIOUR OF INSECTS

THE BEHAVIOUR OF INSECTS

THERE is an American wasp that is fond of a black waterside spider several times larger than itself—or, more accurately, herself. The booty is paralysed, but it is too heavy to fly with, and the vegetation is too thick to allow of land transport by haulage. "Out on to the surface of the placid stream the wasp drags the huge limp black carcass of the spider and, mounting into the air with her engines going and her wings steadily buzzing, she sails away across the water, trailing the spider and leaving a wake that is a miniature of that of a passing steamer." She makes straight for the burrow where her eggs are laid, she hauls the spider up the bank and drags it into the hole to form part of the provision for her young ones. It is this kind of almost incredible behaviour that fills us with amazement; it seems to belong to a different order of things from ours. As Maeterlinck said: "The insect brings with it something that does not seem to belong to the customs, the morale, the psychology of our globe; we cannot grasp the idea that it is a thought of that nature of which we flatter ourselves that we are the favourite children." But while we may never be able to understand ants, bees, and wasps, just because we are as characteristically creatures of intelligence as they of instinct, it should be possible to get nearer them than mere wonder brings us, and a great step towards getting things into order has been taken by Professor E. L. Bouvier in his

Psychic Life of Insects, translated (1922) by Dr. L. O. Howard.

Tropisms

When the caterpillars of the Brown Tail moth are hatched from the eggs, the first thing they do is to climb up the twigs where they find themselves, and this brings them to the young leaves which they require for food. Similarly, the maggots of the bluebottle penetrate into the meat; the mature queens and drones in the bee-hive seek the light of day; ants retreat into their nests when it is too hot or too cold outside, and make straight tracks away from essence of pennyroyal; the male silkmoth is attracted to the fragrance of the female; some aquatic insects always swim against the stream and some flies always make their way against the wind. Now these activities are *Tropisms*, engrained constitutional obligations, in most cases adaptive. An asymmetry of stimulus provokes asymmetry of muscular activity; this automatically results in movements which restore symmetry of stimulus. Whatever may have been the case during the establishment of the tropism, it is eventually an engrained obligation, requiring no will or control, and without any verifiable psychic side. It should be noted, however, that one tropism may influence or counteract another, and that a tropism may change in character with the age and physiological condition of the animal.

Engrained Rhythms

Roubaud has described interesting "house-worms" from Africa, the maggots of a fly, which burrow during the day in the earthen floor of huts, but come up at night and gorge themselves on the blood of sleepers. A periodicity has been established in the body of these insects, and

Roubaud was able to prove that they may be experimentally induced to come up by day or by night according as they are treated. This leads us on to rhythms engrained in the constitution. Some moths are active by day and others by night, just as some flowers open by day and others by night. Some walking-stick insects are absolutely motionless during the day, but begin to explore whenever night falls. There are many internal *Vital Rhythms* which have been punctuated in reference to external periodicities; an organic memory is established which eventually provokes activities independently of the original stimuli. This is not as yet psychism, but it is on the way.

"*Differential Sensitiveness*"

The bed-bug hides from the light; this is its tropism. If it be accidentally exposed to the light, it immediately turns through 180 degrees; this is called its "differential sensitiveness." It is very difficult to make a bed-bug which is on black paper pass over on to a piece of white paper. When the mourning-cloak butterfly is resting in the sunshine, it turns its back to the light; when it is walking or flying it keeps its face the other way. If a shadow be thrown on it when it is walking, it stops, momentarily closes its wings, and then quickly takes flight. This is differential sensitiveness, when animals move away from situations which are unfavourable to the exercise of their normal tropisms. The sudden change provokes an opposite kind of activity which lasts for a time, after which there is a return to the former state or direction; and an important fact is that the sudden change, say a gust of wind, a warm breath, or altering the slope of the surface on which the insect creeps, may reverse the creature's behaviour in regard to some quite different kind of stimulation, such as light.

A well-known expression of differential sensitiveness is seen in cases of so-called "death-feigning." The reaction to the sudden change is abrupt immobilisation. Many a beetle suddenly seized becomes instantaneously rigid and may remain in this condition, though no longer molested, for half an hour. In some cases the muscles pass into a tetanic state, so that a big insect like a water-bug can be held out stiffly by one of its slender legs. In higher animals the catalepsy may sometimes have protective value, but among insects it rarely admits of any utilitarian interpretation. It appears to be an exaggeration of differential sensitiveness.

The "Trial and Error" Method

So far, then, in tropisms, vital rhythms, and differential sensitiveness there is little indication of any mental aspect. Of that the first clear evidence is to be looked for when the creature tries one reaction after another and selects that which is most satisfactory (the "trial and error" method), or when it illustrates "learning," which involves individual associative memory. A wasp struggles ingeniously to get its booty over obstacles; a mortar-bee searches for the shifted snail-shell in which it has laid its eggs, and having found where we have put it retains a memory of the place; a cockroach can be taught by electric shocks to avoid a dark passage in its cage; the sacred scarab that makes balls of dung alters its behaviour according to the nature of the soil; the solitary urn-making wasp Ammophila closes its nest perfunctorily so long as it is not fully provisioned, but when the labour of collecting food for the future larvæ is over, there is a careful blocking of the door and smoothing of the surface. In some cases a little pebble is used as a pounding instrument. Here we see individuality, alternatives, some appreciation of means and ends.

Instinctive Behaviour

The next level of behaviour is instinctive. It includes the innate and automatic capacities of the creature as a whole, a chain of doings which are individually like reflexes but have a psychic as well as a physiological concatenation —"automatisms dominated by cerebral activity." Instinctive behaviour tends to routine, and yet it is often variable; it is not the result of lapsed intelligence, and yet it tends to become more and more automatic. According to Bouvier, one can hardly see in insects "simple reflex machines," as some mechanists have called them, "for they know how to bend to circumstances, to acquire new habits, to learn and to retain, to show discernment. They are, one may say, somnambulists whose minds awaken and give proof of intelligence when there is need for it." But when the instinctive behaviour is most perfect, and seems almost rational, it is probably most divergent from intelligence. "Never are the insects so far from us as when they appear to resemble us most."

Bouvier is neither Lamarckian nor Weismannist, but he inclines to the former more than to the latter. New departures in instinctive behaviour may arise like mutations from some germinal change, but their testing and establishment may require intelligence, and new habits intelligently acquired may add to the patrimony of instinct. There is no faculty of "instinct"; different forms of instinctive behaviour may arise in different ways; instinctive and intelligent behaviour are not of the same order, yet they assist one another at many a turn; they are both "opposites and complements." And the fact that instinctive behaviour reaches its climax in insects and other arthropods is correlated with their particular type of body-architecture, with a chitinous exoskeleton and the muscles inside, with numerous specialised appendages which are like organic tools—usable in certain ways and

not otherwise. The specialised mouth-parts of a bee are the antithesis of man's generalised hand, which is able to do any kind of work, and with this is associated the fact that the bee is predominantly instinctive and man intelligent.

Intelligent Behaviour

But let us complete our ascent of the inclined plane of insect behaviour by citing a case where we should say that intelligence takes the reins. There are predatory wasps called Pompilids that hunt spiders and are very diverse in their behaviour. There is one kind that follows a trapdoor spider down her shaft and stings her there. But in the autumn this spider makes a side shaft with a separate door on the surface of the soil, and this makes capture more difficult. What does Pompilus do? One trick is to carry away the two doors, for this induces the spider to come up to repair the damage. Another trick is to stick its tail into one of the doors and then withdraw quickly to watch the other. If nothing happens, the wasp does the same thing at the other door. A third trick is to give certain knocks at one of the doors, at the same time watching the other. The spider eventually jumps out, a creature of great agility, but the wasp is quicker still! It does not seem too generous to call this kind of behaviour *Intelligent.*

XXXVI

SENSITIVE PLANTS

SENSITIVE PLANTS

COMPARED with most animals, plants seem to live a very sleepy life. They do a great deal of work, especially in the manufacture of chemical explosives and in raising a mass of foliage against gravity, but it is done in a dreamy sort of way. So it seems at least, but we can only guess at the inner life of plants, not knowing how to put ourselves *en rapport* with them. Perhaps it may be said that we know more about the chemistry and physics of plants than about their biology, and that of their psychology we know nothing. This being so, it is of great interest to study plants when they awaken a little to agency, when they bestir themselves to answer back in visible movement.

Movements of Plants

How often we have sat on the dry hillside where the rock-roses (Helianthemum) spread out their flowers in the blaze of the sunshine, closing up when a cloud comes, and touched the central crowd of stamens with the tip of our little finger to see them all bend outwards to the periphery. There is something pleasant in knowing that this movement takes place naturally when the stamens are stimulated by the legs of the appropriate insect-visitor, and that dusting with pollen is thereby affected. But there is another pleasure in following the deliberate outward movement, which only occurs in the warmth of the sun. It brings the plant nearer to us, this answer-back. The

same sort of wakening up is seen when we touch with a bristle the inner side of the base of the stamens of the barberry in the hedge or the related Mahonia in the garden —there is a movement inwards to the pistil. How often we have lingered by the side of the stream to touch with a hair the bilobed stigma of the golden Mimulus, to see it close its lips. There is something pleasant in the fitness of the movement, for in natural conditions it serves to make sure of the pollen grain which has landed between the lips; but there is here also another pleasure, a glimpse of the unity of life, the touch of Nature that makes the whole world kin.

Carnivorous Plants

The margins of the glistening leaves of the butterwort (Pinguicula) curl in a little on the captured insects, and a similar response reaches a very high degree of perfection in the well-known Venus's fly-trap of the peat-bogs of North Carolina. The bilobed blade of the leaf bears, on each half, three sensitive jointed bristles which stand up vertically. When these are touched (the trigger has often to be pulled twice) the two halves of the leaf fold quickly together, and the marginal teeth interlock like those of a rat-trap. Then follow the processes of secretion, digestion, and absorption that make this fly-trap so like an animal's stomach. There are many suggestive details, such as Sir John Burdon Sanderson's discovery that the closing movement of the leaf is accompanied by an electrical change similar to that associated with the contraction of animal muscle. But there is perhaps an even subtler suggestion in the fact that if the fly-trap is cheated several times in succession with useless touches, *e.g.*, of pieces of paper, which bring no booty, it refuses for a brief period to answer back. This looks like the dawn of memory, and if it is, it matters little that the fly-trap's memory should be

a very short one. We do not need to go to Carolina to get a striking example of a plant's power of answering back, for the sundew on the bog-moss carpet is all that we could wish. Its leaves are covered with "tentacles," each with a viscid drop on its tip. When an insect gets a leg entangled in the secretion and begins to struggle, other tentacles are stimulated and more juice is exuded. As the news travels through the leaf all the tentacles curve inwards and close down upon the victim. Secretion of a peptonising ferment follows and then digestion and then absorption; after a while the leaf returns to the normal state of expectancy. We have repeated Darwin's experiments showing how exquisitely sensitive the tentacles are to the least trace of a nitrogenous salt in a drop of water.

Movements of Leaves and Flowers, Shoots and Roots

One of the reasons for the relative sluggishness of plants is that the protoplasm of the vegetable cell is encysted by its cell-wall of cellulose. Like the mediæval knight, as has been aptly said, its movements are checked by its protective armour. And yet, in addition to the cases we have referred to, how much mobility there is, especially in young and actively growing parts. As Darwin first noted, the tip of the growing seedling moves slowly round, bending and bowing to the different points of the compass, and roots move as well as shoots. Leaves rise and fall, flowers open and close, with the waxing and waning light of day, and tendrils are exquisitely sensitive to the touch of the support round which they coil themselves. When we add everything up, plants are much less stationary than they seem.

Professor F. O. Bower's *Botany of the Living Plant* (1923) gives us very vividly the impression of plants as living creatures—struggling for food and light and foothold, growing and moving, feeling and answering back,

overcoming difficulties and establishing inter-relations, multiplying and developing, varying and evolving, making the dry land their kingdom and opening the way to the higher, more wakeful, life of animals—especially terrestrial animals. The same impression is reached along a different path in Sir J. C. Bose's *Life Movements in Plants*, the latest of a remarkable series of studies on the irritability of living creatures. In a general way it may be said that this distinguished investigator has shown the plant to be much more responsive than botanists had suspected and much nearer ourselves than we had dared to believe. "Investigations which I have carried out show that all plants, even the trees, are fully alive to changes of environment; they respond visibly to all stimuli, even to the slight fluctuations of light caused by a drifting cloud."

The "Praying" Palm of Faridpur

It is a pretty story that he tells of the "Praying" palm tree of Faridpur, though it is, as it were, only a picture in his book. The date palm in question, which has died of too much publicity, used to prostrate itself every evening, when the temple bells called the people to prayer. It erected its head in the morning, and so every day of the year to the admiration of the pilgrims. Some storm had probably displaced it from the vertical to an inclination of about 60° thereto, and it was this that made it bend and bow so emphatically, the highest part of the trunk moving up and down through over a yard. The large leaves that pointed high up against the sky in the morning were swung round in the afternoon through a vertical distance of about six yards. "To the popular imagination the tree appears like a living giant, more than twice the height of a human being, which leans forward in the evening from its towering height and bends its neck till the crown of leaves press against the

ground in an apparent attitude of devotion." In such a sentence we feel the Oriental atmosphere, but there is nothing of this in the rigorous analysis with which Sir J. C. Bose showed that the phenomenon of the "Praying" palm is exhibited, more or less, by all trees and their branches, being in fact an illustration of the well-known modifying influence of temperature on geotropic curvature. The tree, apparently so rigid, behaved like a gigantic living cushion (like the pulvinus at the base of the leaf of the sensitive plant) in responding to the diurnal rise and fall of temperature. "The movement of the 'Praying' palm is a thermonastic phenomenon." There is no mistaking the melodious voice of science.

The Sensitive Plant

Many of us have played with the sensitive plant (*Mimosa pudica*), which takes up its sleep position (though not its sleeping condition) when it is touched. Each of the beautiful leaves has four parts or pinnæ bearing crowded leaflets on each side; at the base of each leaflet, of each of the four pinnæ, and of the main leaf-stalk itself there is a motile organ or pulvinus; and all the movements are due to changes in the turgidity of the cells of these cushions. If we hold a lighted match near some leaflets of one of the pinnæ they fold quickly upwards, the message passes to other leaflets and they follow suit, it travels to other pinnæ and their leaflets fold up, the four petioles draw together like a closing umbrella, and suddenly (when the news arrives) the main leaf-stalk sinks down. Haberlandt has shown that the stimulus travels by special elements in the bast of the vascular bundles of the leaf.

Now, it is to this attractive exhibition of sensitiveness and mobility, and to analogous vitality in other plants, that Sir J. C. Bose has given his patient and ingenious attention for many years. He shows us, for instance, that

the lower half of the cushion of the sensitive plant is eighty times more sensitive than the upper, and that the fall of the leaf is due to the predominant contraction of the more excitable lower half; that the excitability of the plant varies throughout the day according to changes of temperature and light; that the plant may suffer from depression and shock, fatigue and ageing, and that it may be refreshed by rest and stimulants; and that the answers it gives depend not a little on the "tone" of the tissues at the time. We feel how wise Linnæus was in uniting plants and animals under the title "Organisata."

The Crescograph

One of Sir J. C. Bose's truly admirable contrivances is called the crescograph, which records automatically and in magnified expression the growth of plants and its variations under different treatment. With growth-measurers (auxanometers) previously in use a magnification of about twenty times was secured, but it took nearly four hours to determine the influence of changed conditions on growth. The crescograph gives a magnification of ten thousand times or more, and reduces the necessary period for experiment to thirty seconds! So may be studied the influence exerted on growth by temperature, chemical excitants, anæsthetics, poisons, increase of turgor (induced by irrigation with cold water and with warm), electric stimulation (often below human perception), light (which antagonises warmth), and other factors in the environment. It has been suggested that the crescograph will advance practical agriculture, "since for the first time we are able to analyse and study separately the conditions which modify the rate of growth. Experiments, which would have taken months and might thus have their results vitiated by unknown changes, can now be carried out in a few minutes."

It was in 1878 that Claude Bernard published his famous book, *Phénomènes de la Vie Communs aux Animaux et aux Végétaux:* how it would have delighted him to know that the speed with which excitations pass through a plant has been measured; that plant excitability and the variations of it have likewise been measured; that there is periodic insensibility in plants corresponding to what we call sleep; that vegetable tissues show like animal tissues the effects of stimulants, anæsthetics and poisons; that a death-spasm takes place in the plant as well as in the animal. It is not a useful expenditure of time to try to show that different kinds of things are the same; and animals are very different from plants when all is said and done; but it is a fine disclosure of the essential unity of animate Nature that we owe to the insight, patience, and manipulative skill of Sir Jagadis Chunder Bose. It is in accordance with the genius of India that the investigator should press further towards unity than we have yet hinted at, should seek to correlate responses and memory impressions in the living with their analogues in inorganic matter, and should see in anticipation the lines of physics, of physiology, and of psychology converging and meeting.

The thrill in matter, the throb of life, the pulse of growth, the impulse coursing through the nerve and the resulting sensations, how diverse are these and yet so unified! How strange it is that the tremor of excitation in nervous matter should not merely be transmitted but transmuted and reflected like the image on a mirror, from a different plane of life, in sensation and in affection, in thought and in emotion! Of these which is more real, the material body or the image which is independent of it? Which of these is undecaying, and which of these is beyond the reach of death?

Here, no doubt, reach exceeds grasp, but that is as it should be.

XXXVII

THE COLOUR OF TROUT AND OTHER FISHES

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WHEN we watch trout in a stream, perhaps from a low bridge, we rarely detect more than flitting shadows. When we look at them in an aquarium or just after capture, we realise their great beauty, though it is admitted, of course, that they differ greatly according to their habitat, food, and idiosyncrasies. The same trout may be brilliant at one time and distinctly off colour at another. According to the British Museum expert, Mr. Tate Regan, the typical coloration is something like this:—

> The colour of the back varies from bluish grey or bright olive through different shades of green, yellow, brown, and violet to nearly black; the sides usually have silvery or golden reflections, and the blues of the back are replaced below by white, yellow, or grey. The spots, black, brown, or red, stellate, round or oval, and often ocellated, differ greatly in their size, number, and distribution.

In a large lake with pebbly bottom the trout are very silvery; in peaty water against a rocky bottom they are often very black; the mollusc-eating "Gillaroo" is often true to his name, which means "red fellow"; and there are many other diversities, to the significance of which we shall afterwards refer. But everyone will allow that a typical trout is a very beautiful fish.

Different Styles of Coloration

It is invidious to compare different kinds of coloration among animals; they are like the styles of different paint-

ers. But there is a peculiar charm, we think, in the colours of fishes; and it is not confined to those we ourselves catch. In the wonderful brilliance of humming birds and birds of paradise and the peacock's tail, or in the witchery of many butterflies, we have to deal with static precipitates of pigment, enhanced by the physical structure of the surface of the feather or scale with its fine laminæ or gratings which cause iridescence. But in fishes (and in cuttlefishes) the coloration is mainly due to actively living pigment cells or chromatophores. We think that a peculiar subtlety is naturally enough due to the pigment being bound up with the protoplasm which ebbs and flows in restless tides within the chromatophores. The same sort of pigment cells are found, it is true, in frogs, chameleons, and their relatives, which appeal less strongly to the lover of colour, but their relative inferiority may be due to the fact that fishes are aquatic animals, and can therefore allow themselves greater artistic liberty than is usually permissible for creatures living on land. Moreover, when we study an Æsop prawn among the seaweed, a crustacean with an extraordinary repertory of colour changes, we see the same liquid colour that we admire in fishes, and here again we have to deal with intensely living chromatophores.

It will be understood that we are not saying that a mackerel has finer colouring than a milkmaid, or that a coral-fish, like a fragment of a rainbow, excels a cockatoo. Such statements have little meaning. What we say is that there is a difference in style between coloration due to static factors (pigment fixed in a matrix that dies, but often enhanced by a finely lined or laminated surface), and coloration due to kinetic factors (pigment borne by the restless living matter of expanding and contracting chromatophores). A third style is familiar in many flowers where the colouring matter is dissolved in the cell-sap, forming coloured fluid in short.

Colour Cells

The colour of the trout is due mainly to numerous irregularly-shaped, very mobile, cells, containing pigment. These chromatophores belong to the under-skin or dermis, but they may lie between it and the outer skin or epidermis. The latter is a very delicate transparent layer, like wet tissue paper, and comes off on our finger and thumb when we lift the fish. The scales, it may be noted, are dermic products, unlike the epidermic scales of snakes and tortoises. They lie in pockets of the skin with only a part protruding, over-lapping one another like the slates on a roof but much more so. The pigment-cells occur both above and below the scales. Their peculiarity is that they contract and expand, and that they show numerous radiating processes of their living matter. In fact they are like very irregular amœbæ. Sometimes a chromatophore is greatly spread out with the pigment much in evidence; sometimes it is contracted down to a biconvex pinpoint, and, if this is general, the ground-colour of the trout is dominant. Any rapid change of colour in a fish is due to the expansion or contraction of the chromatophores, or also to a change in their position in the skin. A slow change of colour is due to an increased accumulation of pigment in the cells, or to the assumption of pigment by cells previously colourless, or to a destruction of pigment-cells by hungry neighbours. There is no use trying to make things simpler than they are.

In some trout, as in salmon, the flesh has a pinkish colour, which is due to oily globules tinged with a ruddy fat-pigment or lipochrome. But we may leave this flesh-colouring out of account, and keep to the pigments in the chromatophores. Here we have to distinguish between the dark-coloured melanins and the lipochromes, which show some shade of red, orange, or yellow. In a goldfish we see how the ruddy lipochrome has got the upper hand

of the melanin. Whatever be their colour, the pigments are by-products of the chemical routine or metabolism of the fish, and it should be noted that there are numerous melanophores that never see the light of day. Thus they occur abundantly on the lining membrane of the body-cavity or in the envelope surrounding the brain. The melanin of the trout has the form of extremely minute dark particles, and it is practically certain that these represent waste-products due to the breaking down of protein material. They form part of the ashes of the living fire.

Silveriness

But there is another factor in the trout's coloration—namely, the presence of cells (iridocytes) containing minute crystal-like spangles of a waste-product called guanin. The reflection of light from these spangles produces the silvery sheen so characteristic of fishes, and here again the creature gets "beauty for ashes." The glistening iridocytes occur especially in a delicate membrane on the under-surface of the scales, and it may be noted that the scales of some fishes are utilised in the manufacture of the frankly artificial Roman pearls. The guanin may also occur on the wall of the body-cavity and swim-bladder; and the familiar silveriness of the down-turned (right or left) side of flat fishes of the sole and flounder tribe is due to the absence of pigment and the abundance of guanin. In association with the chromatophores the iridocytes add greatly to the beauty of the fish, for they produce a metallic shimmer or even rainbow-like iridescence. A well-known Californian species which has been introduced into some British lakes and rivers is called the Rainbow Trout.

Some very interesting experiments on the colour of trout have been made by a Swiss zoologist Murisier. He found

that trout reared in an aquarium with a white bottom or in total darkness are light in colour, the dark chromatophores or melanophores being contracted. But sister trout reared in an aquarium with a dark bottom or in one with feeble illumination (partial darkness) are of sombre colour, the melanophores being expanded. He found that the contracted state of the melanophores is due to the activation of a special nerve-centre in the brain, and this activation may be brought about either by a luminous excitation of the upper part of the retina by light reflected from the white bottom, or by the absence of any retinal excitation in complete darkness. On the other, in dim light or in light that stimulates only the lower part of the retina (an absorbing bottom) the nerve-centre is affected in such a way that the melanophores are maintained in a state of expansion, and the trout are dark in colour. The conditions of illumination do not affect the colour-cells directly, they operate circuitously through the eyes and the central nervous system. Eventually, of course, the orders reach the pigment-cells through the nerve-endings in the skin. To sum up: on a dark bottom or in dim light, trout are dark, with expanded melanophores. On a light bottom or in total darkness, trout are light, with completely contracted melanophores. We are afraid to trench on the question of blind fishes, for it is puzzling; but we may say that here also the nerve-centres are the controlling agencies. In total darkness blind trout behave like normal trout; that is to say, they turn light.

Slow Changes of Colour

From the Natural History point of view the slow change of coloration in trout is not less interesting than the quick change; both suggest the possibility of useful adaptation to surroundings. Murisier has shown that on a dark bottom or in relative darkness there is increased deposition

of black pigment, which may perhaps make the fish more invisible than usual. On a light bottom, as in the clear water of shallow streams flowing over gravel, there is a relatively feeble formation of black pigment, and this again may be useful. And what is true of the amount of black pigment deposited holds in regard to the number of colourless cells that turn into melanophores. There are several reasons, however, why we must not attach too much importance to these utilitarian considerations. In the first place, the coloration is a by-play of the fundamental chemical routine, and perhaps its primary significance is simply as a non-utilitarian expression of individuality and idiosyncrasy. Secondly, we must remember that the coloration is affected not only by the amount of light, but also by the temperature, the oxygenation, the chemical composition of the water, and the food. It is a complex resultant, and perhaps it may also be influenced by the crossing of different races of trout. Thirdly, a trout in total darkness shows arrest of black pigmentation, just as a trout does on a light bottom. But if we attach much utilitarian significance to the light colour of the trout on the light bed of the stream, what have we to say as to the light colour of trout reared in total darkness? This can hardly be regarded as adaptive. For total darkness must be a very rare natural habitat for a trout; and if it were common, it would not be profitable for the trout to be light! Finally, we cannot but ask whether the variably coloured trout may not be credited with a capacity for selecting the environment where it is physiologically most comfortable, which may also be that in which it is safest.

Colour-Change in Other Fishes

Passing from the trout, let us inquire into colour-change in other fishes. We must probe a little further into the

anatomical details. Fine nerve fibres are in connection with the chromatophores, and when these are stimulated there is condensation of the pigment in the cells. In the *medulla oblongata* of the brain there is a nerve-centre that has to do with the colour-change and the messages travel for some distance down the spinal cord, then into the sympathetic system, and thence to the skin. Thus the coloration is under nervous control. Local stimulation sometimes causes change of colour in the skin, but in most cases the message comes from the brain. The importance of this nervous control is obvious. Within certain limits the fish can change its colour, and it does so in response to diverse stimuli—the colour of the ground, the colour of the light, the temperature of the water, and so on. In ordinary cases, adjustment to suit the colour of the ground does not occur in blind fishes; in other words, the colour of the surroundings first effects the eye. But a fish may change its colour during mental excitement, as Frisch has proved for the minnow, and a blind fish shows this as well as one with its vision unimpaired.

Uses of Coloration in Fishes

There are at least four uses that the coloration of fishes may have—(1) protective, (2) aggressive, (3) repellent, and (4) attractive. But which, if any, of these uses a particular fish may illustrate cannot be determined except by experiment, and there have been too few experiments. Nothing is more unsatisfactory than the facile assumption that an interpretation which works well in theory is therefore true to nature, or can be imposed by analogy from one case proved to a score not even tested. That is not the way in which secure science grows. (1) It has often been observed that some kinds of fishes can put on a veritable garment of invisibility. With a young plaice in a shore-pool one can demonstrate this, and repeat some

of the fine experiments made by Professor Sumner, who put flat-fishes on a great variety of artificial backgrounds and photographed the stages of assimilation. They literally fade into their surroundings as if the eye kept sending messages to the brain, and the brain to the spinal cord, and the spinal cord to the sympathetic system, and that to the peripheral nerves, and these to the chromatophores until a harmonious adjustment is arrived at. We believe that we are here very close to a great psycho-biological secret, and, in any case, there are two very noteworthy facts—the nicety of the colour adjustment when it is feasible at all, and the rapidity with which it is sometimes accomplished. In some of Professor Sumner's experiments the flat-fishes succeeded in approximating to a pattern like a draughts-board. In some Australian fishes, of which Mr. David G. Stead has told us, the harmonisation is achieved in the course of a minute or two. But we must not assume without proof that the wonderful adjustment is an adaptation wrought out by natural selection because of its protective value. That the fading into the environment is of life-saving importance must be proved in each case. (2) A second possible utility, perhaps illustrated by the angler or fishing frog, is that the inconspicuousness may enable the fish to get its prey more successfully. The Gyges ring may be used not to ensure safety, but to secure sustenance. It may have aggressive value. (3) It has been satisfactorily proved that some fishes, from the minnow of our streams to the grey snapper of the coral reefs, have a definite colour-sense. They can discriminate colours, and form associations with colours, and retain these associations in their brains, poorly developed as these are. It is, therefore, quite possible that a brilliant colour may be of use as a warning advertisement, testifying to all whom it may concern that this fish should be left severely alone. There is a considerable body of evidence that some unpalatable or poisonous fishes, *e.g.*, the weaver,

get on better because of their conspicuous colours, which have rivetted a noli-me-tangere impression in the minds of the predacious. (4) The fourth possibility is well illustrated by the male sticklebacks in the shore-pools. At the pairing season they are transfigured; they are living jewels of blue and red. It is quite possible that this may render the males more attractive in the eyes of their mates, whom they coax to enter the nest of seaweed they have fashioned. It is certain that a minnow, for instance, can discriminate between certain colours; it has been proved that some fishes can establish a definite association between a particular colour and something they like. Therefore it is quite possible that the brilliant male sticklebacks, and, still more, the males of the gemmeous dragonet which display their beauty elaborately, have their distinctive coloration justified by its value in mating. But definite proof is lacking. Would a male stickleback be less successful in khaki?

Non-Utilitarian Colours

But there are many fishes for whose brilliant coloration no utility is known. This is well illustrated by the coral-reef fishes of the Tortugas, the subject of an admirable study by Professor Jacob Reighard, of the University of Michigan. The fishes are very conspicuous, in no way hidden from their enemies or from their prey. The coloration is the same in the two sexes, and it is not an advertisement of unpalatability. Reighard found that the grey snapper, a predacious fish of the reefs, which discriminates certain colours, forms associations readily, and has a memory, made no bones about devouring twenty species of the brilliant coral fishes. What then is the explanation? Reighard's conclusion is that the brilliant colours are of no use at all. The fishes in question are very agile and very safe in the intricacies of the reefs.

Like humming-birds they have few enemies, and they have let conspicuousness run riot. The coloration is an external expression of the intensity of the vital processes and in the immunity of the organism from the action of selection on its colour characters, it has become exuberant. We believe that this idea must apply to many cases where the often too ingenious utilitarian interpretations of colouring have broken down.

XXXVIII

LIVING LIGHTS

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ARISTOTLE speaks of the luminescence of dead fishes and damp wood, which we know to be due to bacteria and fungi respectively, but long before Aristotle the fishermen must have noticed that the oars sometimes drip sparks and that the breaking waves may gleam with light. In warm countries the bush aflame with fireflies must have been a familiar sight for ages before the marvel of it was recognised, the insect's transformation of energy surpassing in its economy any human invention. But exactly when it was clearly understood that light may be a by-product of vital processes (or metabolism) it is hard to say. Till the beginning of the nineteenth century the luminescence of the sea, which we know to be due to a multitude of small organisms, such as Noctiluca, was a mystery, on a par with St. Elmo's fire at the masthead (a slow brush-like discharge of electricity), or with Will-o'–the-Wisps moving over the swamps (probably due to the combustion of phosphine or of marsh-gas).

In his monograph, *The Nature of Animal Light*, (1920), Dr. E. Newton Harvey, Professor of Physiology at Princeton, notes no fewer than thirty-six orders of animals in which luminescence is known to occur. And that is after excluding many alleged cases, for a "luminous" frog turns out to have dined well on fireflies, and everyone knows that the shining of the cat's eyes in the dark is simply an interesting reflection. Although luminescence

has been sometimes reported from animals living in fresh waters, *e.g.*, in the larvæ of a harlequin-fly, Professor Harvey will not admit that it occurs except on land or in the sea; and he also points out that there is no rhyme or reason in its distribution. It is seen in various Infusorians like Noctiluca, in numerous stinging animals like sea-pens and Portuguese Men-of-War, in the beautiful comb-bearers, in sundry worms and brittle-stars, in many crustaceans and insects, in squids and a few other molluscs, in compound Ascidians like the Fire-flame (Pyrosoma), and in many fishes, especially from the Deep Sea.

Cold Light

More clearly than before Professor Newton Harvey puts animal light in its proper place. A body which gives off light-waves because of its high temperature is said to be incandescent, but when the light emission is stimulated by some other means than heat we speak of *luminescence*, and all animal light—"cold light"—is of this nature. The emission of light by bodies after previous illumination or radiation is called phosphorescence, but animal light is not in this category. Nor is it fluorescence or electro-luminescence or crystalloluminescence—we dare not go on to bigger words still; animal light is due to the oxidation of some substance produced in the cells; it is a chemical or bio-chemical phenomenon. Its physical characters have been carefully studied in luminous beetles, such as "fire-flies," and the important general fact is that it is all visible light, with no infra-red or ultra-violet rays, and that it behaves like light from ordinary sources. "Like ordinary light, animal light will also cause fluorescence and phosphorescence of substances, affect a photographic plate, cause marked heliotropism of plant seedlings, and stimulate the formation of chlorophyll." As Langley and Very pointed out in their well-known paper "On the

Cheapest Form of Light" (1890), the luminescence of the firefly is all light and no heat. It is cheapest in the sense that none of the energy is lost in the form of heat. It is perfect "cold light" and might be taken as an emblem of what scientific illumination ought to be. Moreover, Harvey agrees with Langley that there is no reason why man should not learn the method of the firefly for practical purposes.

The Production of Light by Organisms

The light may be produced only *in situ* in the cells in which the photogenic substance is made, or there may be a luminous secretion which exudes over the surface of the body. This may form a glimmering trail in the sea or on the ground. The production of the light may be periodic, even rhythmic, or it may be continuous. It is interesting to find that some fishes, whose luminous organs are always active, are able to draw a blind over them, or to turn the lighting surface against the body-wall so as apparently to "turn off" the light. When the light comes from an extra-cellular secretion it is usually produced by relatively simple glands, diffusely scattered or definitely arranged. In cases where the seat of the light is intra-cellular, there are often elaborate luminous organs, well illustrated in various fishes, higher crustaceans and beetles, and Professor Harvey lays an interesting emphasis on the fact that these are often very like eyes. In front of the group of photogenic cells there may be a lens, sometimes triple; behind them there may be a reflector; round the sides of the organ and behind the reflector there is often a dark envelope shutting off the light from the tissues of the animal itself; and then there is the nerve, stimulating or controlling. Now many an eye has its lens, its reflector, and its pigmented envelope, so that there is often a very striking resemblance between an organ that produces light and one

that detects light. In the luminous organ, as Professor Harvey says, the important transformation of energy is *chemi-photic;* in the eye it is *photo-chemical.* But the nerve of the luminous organ is of the stimulating efferent order, while that of the eye is sensory and afferent.

Luciferase and Luciferin

Robert Boyle proved in 1667 that air is necessary for the luminescence of damp wood and dead fishes, and the not less ingenious Spallanzani showed in 1794 that while parts of luminous jellyfishes give forth no more light when they are dried, they will emit light as before when re-moistened. Boyle's experiments practically proved that organic luminescence is of the nature of an oxidation; Spallanzani's proved that it is not in the strict sense a vital process. These were first steps in the study of organic light, but there has been great advance since these early days. A very important result was reached by Raphael Dubois, a French zoologist, when he showed (about 1887) that a hot-water extract of the luminous tissue of the boring bivalve Pholas and a cold-water extract of the same, allowed to stand until the light disappears, will again produce light if mixed together. For this led Dubois to the theory that in the hot-water extract there is a substance, luciferin, not destroyed by heating, which oxidises with the production of light in the presence of a ferment or enzyme, luciferase, which *is* destroyed by heating. As Professor Harvey puts it: "The luciferase is present together with luciferin in the cold-water extract, but the luciferin is soon oxidised and luciferase alone remains. Mixing a solution of luciferin and luciferase always results in light production until the luciferin is again oxidised."

For a good many years past Professor Newton Harvey has been following the clue which Dubois discovered, and

in a monograph recently published, he states his conclusions and those of other investigators. As regards luminous beetles, the boring Pholas, and the small marine crustacean called Cypridina, it seems certain that the luminescence is due to the interaction of two very different substances, luciferin and luciferase, in the presence of water and oxygen. The luciferins and luciferases of different animals are different, but all luciferins have a good deal in common and similarly for luciferases. The chemical nature of luciferin cannot be stated at present, but it has much in common with stuffs like digested proteins (peptones).

"Luciferase is unquestionably a protein and all its properties agree with those of the albumins. Although used up in oxidising large quantities of luciferin, it behaves in many ways like an enzyme and may be so regarded." It is calculated that one part of luciferase in 1,700 million parts of water will give light when luciferin is added, and a similar dilution of luciferin will give visible light when luciferase is added. This certainly suggests that luciferase is an organic enzyme or catalyst which oxidises luciferin, or accelerates the velocity of oxidation of luciferin, with the result that light is produced.

Uses of Luminescence

When a living creature simply exudes a luminous secretion or sparkles as it burns up certain complex granules in various parts of its body, it is quite possible that the luminescence is not as such of any importance in the everyday life. It may be no more than the by-play of some physiologically important chemical change. No one feels bound to find a use for the luminescence of bacteria or of the *eggs* of fireflies. But the case is different when there is an elaborate luminous organ or a definite arrangement of organs. The search for a use is then imperative. All

the suggestions that have been made remain more or less of a speculative character. (1) The light may serve to scare away intruders or to distract predacious molesters. (2) The light may be a lure attracting booty in the darkness of deep waters, and this seems plausible when the luminous organ is near the mouth. (3) The light may serve as a lantern, helping abyssal squids and fishes to find their way about. But this interpretation is applicable only when the hypothetical lantern is appropriately situated, which it often is not. (4) The light may facilitate the recognition of kin, and serve as a sex-signal in mating. This fits in well with what is known of fireflies, and it is noteworthy that the toad-fish, Porichthys, is luminous only during the spawning season. It is evident that the chemical physiology of animal light has outrun the theory of its biological significance! It is probable that luminous organs have several different uses. The only certainty is that we must have more facts.

XXXIX

BACTERIA AND LUMINESCENCE

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As we have seen in the preceding study, the physiology of luminescence (popularly and erroneously called phosphorescence) has been carefully studied in the firefly, in a small crustacean called Cypridina, and in the rock-boring bivalve known as the piddock or Pholas. In these cases there appears to be an energetic interaction between a protein substance called luciferase and a somewhat peptone-like substance called luciferin which undergoes rapid oxidation. Just as an active muscle produces heat and electricity, so may another kind of tissue produce light. We do not propose to follow the general question further, but it is necessary to call attention to some recent work, some of which is rather upsetting.

A Striking Case

Not very long ago, Professor Newton Harvey studied two luminous fishes (Anomalops and Photoblepharon) common off the Banda Islands of the East Indian Archipelago. They have very large luminous organs, and they give out light without ceasing, by day as well as by night, and without requiring any provocation. This is unlike what occurs in other luminous fishes, where the light-producing material shines under the influence of certain stimuli, and is generally regarded as a secretion of glandular cells.

In the Banda fishes the investigator could not demonstrate luciferin and luciferase, but under the microscope he found innumerable motile bacteria, and the suspicion arose in his mind that they were the cause of the light! For it is well known that there are various luminescent bacteria, such as those which make dead fishes "shine in the dark." Professor Newton Harvey then found that, if the organ was dried and moistened again, it gave only a faint light, which is also true of luminous bacteria; whereas the luminous organs of most animals can be dried without much loss of their light-producing power when re-moistened. Again, the light was extinguished without a preliminary flash by the addition of fresh water, which is likewise true of luminous bacteria. Poisons that put out the light of luminous bacteria had a similar effect on the light-organs of the fishes in question. So the suspicion grew into a hypothesis: that the light-organ of the Banda fishes is an incubator for the growth and nourishment of luminous bacteria living in partnership with the animal.

Why, it may be asked, did not the investigator discover there and then whether the bacteria were the agents in producing the light? But he could not isolate them within the organ, and when he got them to grow by themselves in a jelly culture, they gave forth no light. This may mean that the hypothesis is wrong and that the light is produced by the living cells of the fish. Or it may mean that the bacteria will not light up except in certain surroundings and with certain food-supplies. It may be that they are not happy, so to speak, when the partnership is dissolved. Further experiments will answer this question.

Borrowed Lights

The case of the Banda fishes makes one ask whether there are many cases of luminescence due, or probably

due, to partner-bacteria, and much information on this subject has been recently made available by Professor Buchner in his great book on *Symbiosis*—that is to say, the living together of two kinds of creatures in mutually beneficial internal partnership. The theory that the luminescence of an active animal might be due not to its own laboratories, but to the intense life of partner-bacteria, is not a new idea, but it has been usually regarded as having a very restricted application. Recently, however, numerous instances have been observed similar to that of the Banda fishes, which indicate more or less convincingly that luminescence is another pie in which bacteria have their finger.

In two families of beetles, the fireflies and the Pyrophores, there is brilliant luminescence, which often seems to be used in love-signalling between the sexes; and the generally accepted view has been that under nervous stimulation a ferment like luciferase produces or accelerates oxidation in a luciferin, with light as the result. In some cases the light-production is very definitely localised —for instance, in two eye-like lamps on the thorax of the large "Cucujo" of Tropical America. It is a remarkable fact that the eggs and grubs are luminescent as well as the adult; the torch is handed on from generation to generation. But this is not unlike bacterial infection. The luminous organ may be reduced to powder and shaken up in water; what passes through filter-paper is still luminescent for a while. But this is again suggestive of bacteria, and so is the frequently observed continuation of the light after the death of the insect. The light is often unequal in the two sexes and at different times, which is against the bacterial theory; and yet we know in the case of diseases that the activity of bacteria may vary according to their vital "soil" and at different periods. Luminous bacteria give out light continuously, whereas the animal light seems often to be interrupted; but it is

possible that the apparent discontinuity is merely a contrast between very dim and very intense luminosity. Finally, in the cells of the insect's luminous organ there are crowds of granulations believed to be photogenic, but the supporters of the new theory declare that these are the partner-bacteria. What is needed is a culture of the alleged partners away from their insect host, and evidence that light can be produced under these conditions.

The Fire-Flame

One of the most astonishing animals of the sea is the Fire-Flame, or Pyrosome, a tubular colony of pelagic Tunicates, brilliantly "phosphorescent" with greenish-blue light or with changing colours. The colony may be as long as one's arm, and a big one will light up a dark room so that the furniture can be seen. A common size is the length of one's hand. The wonderful light is discontinuous, and the lighting-up seems to require a stimulus, such as a touch or a splash from a wave. When the Fire-Flame is kept in an aquarium, it is brilliant for a time, and then the light fails. Both these facts seem to be against the bacterial theory of the luminescence. When a Fire-Flame is carefully examined, it is seen to be a tubular colony of thousands of individuals, and each individual has two luminous organs or spots like little jewels. In the cells of these small spots there are rod-like and horseshoe-shaped corpuscles of very minute size; and here the divergence of opinion again arises, for, while the old view regards the corpuscles as belonging to the Pyrosome itself, the new view interprets them as luminous partner-bacteria.

Luminous Cuttlefishes

The luminous organs of Fire-Flames are simple spots, but in many cuttlefishes they are very complex structures.

They may include a lens, a reflector, a dark envelope, and a central mass of light-producing cells. Inside these cells, according to Pierantoni, there are myriads of bacteria, sometimes hunting in couples. Moreover, in many females there are "nidamental" organs, usually regarded as having to do with the making of the egg-shells, and these, according to Pierantoni, are crowded with the bacteria. It almost looks as if they were organs for incubating the partner-bacteria. As to the presence of the bacteria there is no doubt; but the evidence that they produce the light does not appear to us to be convincing. And it is difficult, surely, to think out the evolution of an eye-like structure around a horde of tamed intruders.

Professor Buchner is satisfied with the evidence that the luminescence of Fireflies, Fire-Flames, and Cuttle-fishes—three very diverse types—is due to luminous bacteria which have established a partnership or symbiosis with the animals. More than that, he thinks it is time to ask whether any multicellular animal produces its own light! Perhaps their luminescence is always a borrowed splendour after all!

Personally we are not convinced that the evidence submitted justifies such a sweeping generalisation, especially in cases where there is an elaborate eye-like luminous organ. But it is plainly a scientific duty to give the new theory careful consideration.

XL

THE AGE OF THE EARTH

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AGAINST an early deductive view that a period of 6000 years was about enough, we have a distinguished geologist claiming that the more or less solid earth began 861,000,000 years ago. He was often asked if he was sure as to the third figure in his estimate, but his answer was always the same, that the sum figured out in that way. The certainty is that the earth has an antiquity beyond our powers of conceiving and the most interesting question is how the scientific estimates have been arrived at, and why they should be so discrepant as they are. It may be mentioned at once that the discovery of radio-activity has affected the validity of all the previous limits which the leading physicists, like Lord Kelvin, had set to the demands of geologists and biologists.

Lord Kelvin's View

The earth was supposed to be a self-cooling body; and investigators expert in such matters were able to argue back to the time when it ceased to be molten (if it was ever molten!). Arguing on these lines in 1862, Lord Kelvin estimated the age of the earth as a cooling body at something unthinkable between 20,000,000 and 400,000,000 years, with a probability of ninety-eight millions. But just as geologists began to be aware of the enormous thickness of second-hand or sedimentary rocks in the

earth's crust—perhaps over sixty perpendicular miles of them when all the quite different series are added up!—Lord Kelvin began to be less generous. He cut down the allowance in a cruel way when indulgent supplies were needed. It was about 1897 that he said:—"We have now good reason for judging that the consolidation of the earth was more than twenty and less than forty million years ago; and probably much nearer twenty than forty." From four hundred millions to forty millions was a bad drop—accompanied, too, by the threat that the allowance might have to be cut down to twenty millions! The biologists were ill at ease, for it takes a long time to make a system of animate Nature on Darwinian lines. They say it may have taken a million years to give the elephant his trunk, and there were many more important affairs than that. The fact is that Lord Kelvin was much influenced by some subtle inquiries into the tides and the moon—inquiries rather beyond the reach of most of us. How long had it taken to get the tides into the state in which they are now? Or how much time had elapsed since the moon was heaved off from the hot earth? There are ways of answering these questions.

There seems to have been some unholy joy in certain camps when Lord Kelvin refused to allow the geologists and biologists all the time they asked for. But even a reduction to twenty millions was far from being an approximation to the 6000 years which those who "wrested the Scriptures" held out for. The grandchildren are now deciphering *man's* records older than the grandparents would allow the earth to be.

Radio-Activity

In any case Lord Kelvin was wrong, for he was unaware of radio-activity. There is enough radium and uranium in the rocks of the earth's crust to make the earth in some

measure a self-heating body; and this fact vitiates the calculations Lord Kelvin and his contemporaries made. As Lord Rayleigh said in 1921—"Radio-active methods of estimation indicate a moderate multiple of 1000 million years as the possible and probable duration of the earth's crust as suitable for the habitation of living beings." If this is sound, our geological friend was well within his rights in asking for 861,000,000!

Some years ago Sir Ernest Rutherford inquired into the radium content of a uranium mineral found in Glastonbury granitic gneiss of the Early Cambrian. His question was how long it must have taken this radium content to form, and his answer was 500,000,000 years. And that liberal allowance of time was for the Early Cambrian alone! But we do not know whether this calculation holds to-day. These young sciences change rapidly.

Other Estimates

There are various ways of getting at the age of the earth from the geological side. As everyone knows, the surface of the earth weathers away; the mountains are always flowing into the sea. There are delivered into the sea every year from the United States alone 783,000,000 tons of rock materials. The average rate of denudation for North America is a foot in 8600 years. The solid particles and fragments that result from erosion go to form sediments, and the dissolved matter may be captured by animals whose shells also go to form sediments. Thus in the past there have been formed the sedimentary rocks, *e.g.*, the sandstones, mudstones, and limestones that form a large part of the earth's crust. Now if all the thicker beds of sandstones, mudstones, and limestones that have been formed at different times be pieced together in vertical sequence, they make a pile fifty-three miles in thickness

as a mean estimate, with a maximum thickness of about ten miles more. It is evident that the time required to erode the ancient rocks and remake them as sedimentary rocks must be prodigious. The calculation makes the assumption that lies at the roots of uniformitarian geology, that the rates of erosion and deposition have not been in the past very much greater than they are today. This assumption obviously suggests caution and the desirability of confirmatory evidence.

The Saltness of the Sea

So we turn to another method which takes us back to the time of the ingenious Edmond Halley, who was the first astronomer to predict the return of a comet. About 1715 Halley suggested that the earth's age might be computed from the amount of common salt in the sea. For all the sodium chloride in the sea is the outcome of sodium filched from the rocks by rain and rivers, and brought to join its equivalent of chlorine in the sea. It is calculated that the sea receives every year 63,000,000 tons of sodium in solution. The primordial sea-water was relatively fresh, and it is possible to calculate from its annual income how long the sea has taken to become as rich in salt as it is to-day. The answers given have, as usual, varied considerably; thus Professor Joly estimated 90–100 million years, and Professor Sollas 80–150 millions. Allowing something for a greater supply of sodium in early days, when the bulk of the earth's surface was covered with granitic and igneous rocks, we may take 100,000,000 as an average of the computations by various investigators.

General Result

The present-day position has been recently stated by a distinguished American geologist, Professor Schuchert.

Since the discovery of radium all the calculations previously made, have been set aside by the new school of physicists, and now geologists are told they can have 1,000,000,000 or more years as the time since the earth attained its present diameter. . . . Even if finally it shall turn out that the physicists have to reduce their estimates as to the age of certain minerals and rocks, geologists nevertheless appear to be on safer ground in accepting their estimates than those based either on sedimentation, chemical denudation, or loss of heat by the earth.

We have touched but lightly on a very difficult subject, in regard to which anything like dogmatism would be foolishness. Yet the general result of increased knowledge has been to show that the drafts which geologists and biologists draw on the bank of time are likely to be honoured. We have said almost nothing about the length of time required for organic evolution, for the data as to the rate of evolution are very precarious. We know from the rock record when certain types—say the Flying Dragons—appeared and when their dynasty came to an end. The geologists can give us some indication of the fraction of the total duration that must be granted to a given epoch. If, then, we accept a total like the 861,000,000 years already referred to, we can tell approximately when the Pterodactyls began and when they ceased to be. But the less we say about the rate of organic evolution the clearer will be our intellectual consciences.

XLI

HOW THE ELEPHANT GOT ITS TRUNK

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ONE of the disappointments which the impatient evolutionist soon meets with is the lack of data in regard to the pedigree of many of the most interesting types. The origin of birds, for instance, remains obscure, except that we are reasonably certain that they sprang from a stock of extinct reptiles, a sub-order of the Dinosaurs. Or, again, the origin of backboned animals is a problem still unsolved; its discussion is hardly beyond the speculative stage. On the other hand, there are some cases where the lineage has been well registered in get-at-able fossil-bearing rocks, so that the story has been clearly read. One of these cases is the elephant.

Modern Elephants a Climax

Every age has its giants, and those of to-day are the whales, the giraffe, and the elephants. The African elephant, according to Sir Samuel Baker, reaches a height of 12 feet; and we know that the once-famous Jumbo stood 11 feet high at the shoulder and weighed 6½ tons. An average pair of tusks may weigh 75 pounds and 65 pounds, left and right respectively, and Sir Samuel Baker reports one that had the prodigious weight of 188 pounds! Yet in spite of its gigantic size the elephant can keep up a speed of ten miles an hour for a long distance. The Indian elephant is not quite so huge as the African species, but is

nevertheless a Colossus. So was the woolly mammoth of the Siberian forests—a Goliath whose David was primitive man. He not only killed him; he drew him on the walls of the caves. There was once an African species bigger still, standing about 13 feet high. We are not forgetting the dwarf or "pony" elephants whose remains are found in Malta, but our point is the obvious one that the true elephants of the genus Elephas are mostly giants. How, then, and where did the race of giants begin?

Pioneers

Millions of years ago, in the Eocene epoch, when there was a warm and moist climate and luxuriant vegetation in many parts of the world, when grassy plains were established in many places, there lived in North Africa a primitive hoofed animal called Moeritherium. It was about the size of a tapir or of a small donkey. Unless the skull is very deceptive, this ancestor of the elephants, for such it is, had, like the tapir, a short snout, useful for gripping the herbage. An elephant's trunk is a prolongation of the nose and the upper lip, and there is an indication of it in various mammals. Thus it crops up in the desman of the Pyrenees, an aquatic relative of the mole, which used to be represented in Britain. In this creature the flexible proboscis is used in catching small water animals, and it is said to be capable of being curved round so as to push food into the mouth—which the elephant does with its trunk. This is Nature's way, to take a very old thing—in this case the upper lip and the nose—and make out of it a very new thing—namely, a flexible trunk.

But we are wandering away from the Moeritherium, whose remains are found in considerable quantities in the region known as the Fayum, in Lower Egypt. Apart from the large nasal opening in a somewhat backward

situation (indicative of a proboscis), the primitive creature had the second incisors on the upper and lower jaw enlarged into tusks, the grinding teeth were transversely ridged, and the bones of the back of the skull were beginning to be lightened by air-cells.

Progress in the Proboscis

Ages passed, and alongside of Moeritherium there emerged in the Lower Oligocene a larger creature called Palæomastodon. It stood from 4–6 feet high, according to the species. The snout had lengthened, the nose-opening was further back, the canine teeth had disappeared, and likewise the front teeth, except two pairs of tusks; there were more ridges (namely, three) on the big grinding molars, and there were more air-cells at the back of the skull. In short, the Palæomastodon was much nearer the elephant. It was also an Egyptian mammal, and it was kept from spreading to the north by a broad and deep sea which united the Atlantic to the Pacific. There is a gap in the rock-record through the Upper Oligocene, but in the Miocene there appeared the triumphant Tetrabelodon, as large as a medium-sized elephant. Its remains occur in Europe, Asia, and North America, as well as in Africa, so the great sea previously referred to must have been, in part at least, replaced by land. In Tetrabelodon the nostrils are still further back, the upper tusks have grown stronger, the grinding teeth have more ridges, the skull has more air-cells. It is probable that there was still a stiffish snout, supported by the elongated front of the lower jaw, but according to the leading British authority, Dr. Charles W. Andrews, in his masterly British Museum Guide to the Elephants (a scientific romance costing one shilling): "the end of the upper lip and nose was probably free and movable, and may even have been able to grasp objects to some extent."

While the race of elephants was increasing in size, the neck was getting shorter; for such a big head could not be borne on a long neck. It follows that if the animals were to continue to be able to reach the ground the snout would have to become longer. It is very interesting to find in the earlier species of Tetrabelodon a long lower jaw with tusks suited for grubbing in the earth, while in the later species the lower jaw "was shortening up and could no longer reach the ground, but doubtless the fleshy upper lip and nose, now freed from their bony support for at least part of their length, became flexible and better adapted for grasping the animal's food." This is how the elephant got its trunk, *pace* Mr. Kipling.

The Modern Elephant

Ages passed, and in the Pliocene epoch there appeared the elephants proper, in some ways linked back to Tetrabelodon by the Mastodons. The shortening of the chin continued and the lower tusks fell away; the back teeth became more complicated, with an increasing number of transverse ridges; the upper tusks grew stronger and the trunk grew longer. To support the great tusks and the grindstone-like molars meant an enormous skull, which was also of service to afford insertion-surface for the strong muscles of the trunk—able to lift a tree. But the increased development of huge air-cavities in the skull-bones counteracted the tendency to an over-increase of weight. Improvements went on hand in hand—in correlation.

The elephant is a big bundle of fitnesses, and we must not forget the remarkable straightness of its limbs—that is to say, the absence of angles at the joints. This is also seen in some extinct mammals of gigantic size, such as Titanotherium, which do not belong to the elephant alliance. But Professor H. F. Osborn is probably right in interpreting the vertical pillars not as primitive features

but as secondary adaptations to support the huge bulk. Another interesting characteristic of the elephant's limbs is the way they end. There are five digits on both fore and hind feet, but these are embedded in a huge cylindrical mass of flesh and skin, so that only the tips of the hoofs are seen on the under surface.

General Reflections

Evolution is a formula for the way in which living creatures have come to be as they are—new kinds arising out of old kinds and often ousting them. It is not the sort of conclusion that can be proved, as one can prove the conservation of energy in an experiment or the change of uranium into radium. But it is the only conclusion open to us, and it is a key that fits. Obscurantists who call for proofs should study the patient work of palæontologists, like Dr. Andrews, who have worked out the pedigree of the elephant. It is as convincing as the pedigree of the horse.

One cannot but be impressed by the bigness of the change from the little Moeritherium of the Eocene marshes to the giant elephants in the jungle, and yet, from another point of view, one is impressed by the leisureliness of the process. They say it must have taken about two million years to get rid of the lower tusks. Of course, elephants are long-lived, slow-breeding animals.

In the story of the elephant we got glimpses of the plus and minus method of evolution. The process of transformation works by adding on—more and more folds on the massive molars, longer and longer tusks, stronger and stronger musculature in the trunk, more and more convolutions in the cortex of the fore brain. But it also works by cutting off—shortening the lower jaw, getting rid of the lower tusks and the canines, reducing the number of back teeth; and the striking thing is that

parallel changes of adding on and lopping off seem to have taken place independently in widely separated parts of the world. This shows that they are under "the reign of law."

Another glimpse of Nature's methods we have already alluded to—the making of the new out of the old. The great tusks, what are they but overgrown incisor teeth? The extraordinary ridges of the molars, what are they but exaggerated plaitings of the enamel into the ivory? The mobile proboscis, able to lift a needle or a log, a penny or a pail, what is it but an extraordinarily long nose, with something due to upper lip? The nostrils run the entire length, and the tip bears a delicate finger-like process in the Indian elephant, two of them in the African species.

But it may be said that all this does not tell us how the elephant got its trunk, but only the stages in the process of acquisition. The honest answer is that we cannot go much further at present. The germ cells are fountains of change—something new is always welling forth. We can suggest reasons why this should be so, but that is another story. What is certain is the continual crop of novelties arising from within, but determined in some measure by what has gone before, and in some measure by the nature of the material. But given the novelties—often outcropping in correlated groups—and given the sieves supplied by the struggle for existence within the system and economy of animate nature, perhaps we need no more to understand how the elephant got its trunk.

XLII

THE ORIGIN OF LAND PLANTS

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THE more one thinks about the conquest of the dry land by adventurous animals of aquatic ancestry, the more convinced one becomes of the impossibility of success if plants had not led the way. Plants ensured the food, the moisture, the shelter without which the dry land would have been altogether too inhospitable for animals. Thus the problem of the origin of land plants has an enhanced interest.

Marine Plants First

It seems quite certain that many ages passed before there were any land plants at all. In Cambrian, Ordovician, and Silurian strata there are plenty of traces of seaweeds, but there are no known fossil land-plants, before the Devonian. Among the earliest are the very interesting Devonian fossils discovered a few years ago at Rhynie in Aberdeenshire by Dr. Mackie of Elgin. Of course it is quite possible that there may have been pioneer land plants long before the Devonian, but of a type too simple to admit of definite fossilisation.

The Colonising of the Land

If there is any orthodox view or majority report in regard to the origin of terrestrial plants, we suppose it

would be something like this: the simplest plants began in the sea and flourished there for ages, but some of them, obedient to the universal impulse to explore empty corners, made their way from shore to estuary, from estuary to river, from river to lake, from lake to swamp and marsh, and thence, at last, began to colonise the dry land. At each station in their ascent some would no doubt settle down and specialise as best they could in relation to the immediate environment, while others would push on, trying as it were to find something better. Whether some may not have passed directly from the sea-shore to the shore-marsh and thus on to dry land, without serving an apprenticeship in the fresh-waters, is a question in detail which many be waived for the present. But the general idea of the theory sketched is that relatively simple plants, endowed with considerable travelling power, like many of the unicellular algæ, did the exploring, and that structural evolution began afresh, as it were, in the successive stations where they established themselves. One must remember that detached propagative parts of plants would not readily migrate up-stream, though spores might be borne by the wind. Fishes may have helped in transport, but there were no plant-distributing birds in those early days. Moreover, there were no true seeds before the Devonian. The general idea seems to be that very simple plants did the travelling, and that when they reached a suitable resting-place they proceeded to evolve into organisms like our liverworts, mosses, and ferns, building up structural complexities somewhat similar to those that had already been achieved among seaweeds in salt water, similar yet different, being adapted to the quite novel conditions of terrestrial life. In his masterly book, *The Origin of a Land Flora* (1908), Professor F. O. Bower has sought to show how the exaggeration of the spore-bearing (sporophyte) generation and the suppression of the sex-cell-bearing (gametophyte)

generation, a change characteristic of all flowering plants, would follow as a natural outcome of plants establishing themselves in a terrestrial habitat. But the prior question is how the transition from aquatic to terrestrial (or subaërial) conditions may have been effected.

A New Theory

To this question a new answer has been recently given by the distinguished Oxford botanist, Dr. A. H. Church, in an essay entitled *Thalassiophyta and the Subaërial Transmigration* (1919), an essay as full of suggestive ideas as it is of repellent terms. We seldom came across a book so gratuitously discouraging to the reader, and yet such good sport from cover to cover. Dr. Church's general idea is that terrestrial plants arose by the gradual transformation of highly-evolved marine plants on a slowly rising beach. Transmigration seems to mean "transition *in situ*." "When the first land gradually lifted above the primal sea, bearing all forms of marine life on it, the successful transmigrant algæ of the first land-migration combined the best and highest factors of marine equipment." What had been gained in the sea in the course of ages was not lost, to be invented *de novo* a second time, it was adapted. It was not in the reproductive part of the plant that the profoundest changes were necessary, it was the body that required to be readjusted from life in an aqueous food-solution to life in an atmospheric medium with no external food-solution beyond the soil-water bathing the roots.

Three Epochs in Plant History

After the gradual cooling of the earth there were, according to Dr. Church's picture, three great epochs of world-construction, with associated vegetations. There

was the time of the condensation of water-vapour to form the sea, which he supposes to have covered the earth, and the surface-waters of that sea were peopled by microscopic plants sufficient unto themselves. This was the *Plankton Epoch.* Second, the folding of the earth's crust raised parts of the floor of the sea within the reach of light, and minute plants began to settle there, anchoring themselves and proceeding to build up fronds and other forms of body. But anchoring on a substratum made it necessary to have some new arrangements to secure dispersal—a return to the plankton phase for processes of reproduction, much in the same way as we see in sponges which liberate free-swimming embryos, or in zoophytes which liberate swimming-bells or medusoids. A new note was struck: the types that survived were those whose individual members had moved in the direction of race-continuance—the most fundamental of all biological truisms. To the plankton-law of self-preservation was added the benthos-law of race-continuance. "The fact that any race still exists implies that the individuals collectively have done their bit." This was the *Benthos Epoch.* Third, there was the gradual emergence of dry land and the gradual transformation of aquatic vegetation—seaweeds in short—into a land-flora, able to absorb gases from the air and salts in solution from the substratum. The Benthos introduced the new factor of substratum, but the emergence of the land introduced the new factor of atmosphere. This was the *Xerophyte Epoch.* In other words, we must think: (1) of the primal Open Sea, with its free-swimming minute green plants; (2) of the floor of the illumined shallow sea with its anchored fronds all intent on experiments in body-making on the one hand and in reproductive dispersal on the other; and (3) of the beach slowly rising, foot by foot, millennium after millennium, with its highly evolved seaweeds slowly transforming themselves into land-plants.

Sieves in Evolution

The energy of growth, at bottom a phase of chemical (ionic) activities, supplies the driving-power of life, and such "life" beats against the sieve of Natural Selection; but this alone does not account for all the manifestations of plant-organisation. *Twice* in the history of the world the sieve itself has been changed: the "hidden hand" which did this, and so determined the path to be taken as a sequence of progression, was not "Nature" or "Divine Guidance," except in so far as such expressions may be utilised to cover an inevitable march of events, but in this case merely the expression of the cooling of the earth, which (1) lifted the sea-bottom by tectonic changes, and (2) ultimately lifted the "land" above the surface of the water, to be subjected to subaërial denudation to form "soil."

Of course, only a few of the plankton creatures got through the sieve to become anchored seaweeds on the subtratum, and only a few of the benthic plants got through the new sieve to become the pioneers of a land flora. The idea of an evolution of sieves as well as an evolution of the sifted material is useful, but we should not be inclined to restrict the operations of the "hidden hand" to *twice*.

Transformation of the Seaweeds

It is very impressive to visit a rocky foreshore at the lowest tide, to wade out among the Laminarians and other seaweeds not usually exposed at all, to observe the vigour and manifoldness of their growth and the complexities of their structure, and to realise that one is moving amid an antique vegetation, some members of which may be much older than the hills. The conventional view is that these seaweeds represent a gorgeous blind alley, but Dr. Church asks us to consider the possibility that from among

such highly evolved creatures the land flora may have emerged by gradual transformation as the foreshore slowly rose. The transformation cannot be thought of in any easygoing way. It meant that the seaweeds' gripping structures, mere holdfasts, not true roots at all, became provided with rootlets and root-hairs suited for the absorption of water and dissolved salts from the soil. It meant that a frond-surface, adapted for the absorption of watery food-solution, became fit for the absorption of the dry gases of the air. It meant the elaboration of a complicated vascular system for conveying the raw materials and the elaborated materials from part to part. These are the more readily stated difficulties which are faced and ingeniously countered by Dr. Church.

Many a plant is a very plastic or modifiable creature, and even such a stable structure as a tree can adapt itself almost out of recognition to unusual conditions of life. It may be that individually acquired modifications hammered on each successive generation of seaweeds on the rising shore, but never taking hereditary grip (for that would be Lamarckism!), served as life-saving screens until germinal variations in the same direction had time to establish themselves as appropriate somatic adaptations.

The migration theory of the origin of land-plants, with which we started, is not an easy theory. Fresh-water algæ are rather of the nature of "depauperated relics." "To pass from the sea to fresh water implies starvation and deterioration of the output of reproductive cells, and hence failure to compensate the wastage of the race, and extinction." Perhaps this smacks a little of *ex parte* judgment, but there is the further difficulty of thinking of simple migrants from pond and swamp beginning *de novo* the elaboration of structural equipments which many of the seaweeds had already achieved. In place of this theory Dr. Church offers us "the epic of the stupendous epoch of a world-transmigration."

The cells and somatic organisation of all land-plants, as also all their reproductive cycles and mechanism, are but the continuation of the mechanisms evolved in the sea, to suit the conditions of life in the sea, as the best response possible under such conditions; and though the mechanism may be emended, modified or superseded in innumerable details, the primary plan of the architecture and the entire range of general principles of organisation remain essentially marine.

Such a view certainly deserves careful consideration. It is in general idea in harmony with what we learn so often in the study of animal evolution, that apparent novelties are only very old structures transformed. New lamps out of old has been one of the great methods of evolution. And as to the maternal sea, why, its tides still echo in the chemical composition of our blood!

XLIII

THE ROMANCE OF THE WHEAT

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WE remember seeing half a century ago in the Lowlands of Scotland the carting home of the Maiden, the last sheaf from the last outstanding field of corn. It was part of the Kirn festival, the English harvest home, and, we suppose, the decorated sheaf stood for Ceres, as the word cereal suggests. We did not understand then how much there was to be grateful for—that the sheaf of wheat was the consummate instance of man's co-operation with Nature. For, within the limits of the ponderable, was not the discovery, and cultivation of the wheat the most far-reaching of all man's doings? Even in relation to the life that "means more than food," we cannot go far without our daily bread, and for a large fraction of our race that is made of wheat. Where did wheat come from? What is the science of Demeter's gift?

"History celebrates the battlefields whereon we meet our death, but scorns to speak of the ploughed fields whereby we thrive; it knows the names of the king's bastards, but cannot tell us the origin of wheat. That is the way of human folly." These two sentences from J. Henri Fabre, obviously written long before Mr. H. G. Wells' *Outline of History*, are set in the forefront of one of the most fascinating of recent books, Professor A. H. Reginald Buller's *Essays on Wheat* (1919). We wish to select from this scientific romance some pictures that give us a glimpse of the history of the most useful plant in the world.

Pre-historic Wheat

It is well known that Neolithic man grew wheat, and some have put the date of the first harvest at between fifteen thousand and ten thousand years ago. The ancient civilisations of Babylonia, Egypt, Crete, Greece and Rome were largely based on wheat, and it is highly probable that the first great wheat fields were in the fertile land between the Tigris and the Euphrates. The oldest Egyptian tombs with wheat, *which never germinates after its long rest*, belong to the first dynasty and are about six thousand years old. But there must have been a long history before that.

The Wild Wheat of Hermon

Now, while everyone knows something about wild oats, and a few know a little about wild barley and wild rye, it was not till the beginning of this century that wild wheat was discovered. It grows on the slopes of Mount Hermon. It is true that a botanist called Kotschy had collected it and pressed it in 1855 and that Körnicke had named it in the herbarium at Vienna in 1873, but it was not till 1905 that Aaron Aaronsohn, Director of the Jewish Agricultural Experiment Station at Haifa, in Palestine, following the hint from Germany, had the good fortune to find the living plant growing in considerable abundance and exhibiting notable variability. "It grows only upon the slopes of the most arid and rocky hills, and in places exposed to the hottest rays of the Oriental sun." The idea that *Triticum hermonis* is an escape cannot be entertained for a moment; it behaves in every way as a truly indigenous plant.

It cannot be circumstantially proved that the wild wheat of Palestine is the veritable ancestor of all the culti-

vated wheats (always excepting the einkorn, which stands by itself and does not produce fertile hybrids when crossed with other kinds), but it is certain that if another ancestor is found it will be very like the Hermon species. One of the primitive features is the possession of a fragile rachis (the axis bearing the spikelets), which breaks readily into segments so that the seeds fall apart and are scattered. This character, well seen in the wild wheat of Hermon and in wild grasses related thereto, persists in inferior cultivated wheats like emmer, spelt and einkorn; in the others it has been replaced by a rigid rachis which is very much better for thrashing, though a hindrance in natural dissemination. According to Aaronsohn, there is strong evidence for regarding the Hermon wheat as the ancestor of emmer, which was cultivated in the Neolithic Age, and emmer as the ancestor of all the ordinary wheats. So we must think of Neolithic man noticing the big seeds of the Hermon wheat, gathering some heads, breaking the brittle rachis in his hands, knocking off the rough awns or beard, bruising the spikelets till the glumes or chaff separated off and could be blown away, chewing a mouthful of the seeds—and determining to sow and sow again.

One of the interesting peculiarities of the wild wheat of Palestine is that it is well adapted for cross-pollination by the wind, though self-fertilisation also occurs. The interest of this observation is twofold: (1) that most grasses have flowers adapted for cross-pollination, so that in this respect the wild wheat is like the majority of its kind; but (2) that most cultivated wheats show self-pollination, though the other method tends to occur in warm countries. According to Professor Buller, "we may therefore regard our cultivated wheats as sexually degenerate. Since the wild wheat of Palestine has cross-fertilised flowers, there seems good reason for supposing that in our cultivated wheats self-pollination came to

replace cross-pollination under conditions of domestication." What usually happens in our wheats is this: at the flowering time, when the temperature is suitable, the glumes diverge rapidly and suddenly, often in the early morning; the filaments of the stamens grow quickly, the anthers project, open, and empty about a third of their pollen on the stigma of the same flower, the rest being scattered in the air. This takes about a minute, and after a quarter of an hour the glumes automatically close again. The first flowers to open are about the middle of the ear, and the process spreads gradually upwards and downwards for the space of four days. Fertilisation has been effected.

Variability of the Wild Wheat

The wild wheat of Hermon is a virile plant, able to look after itself. It is marked by grass-like habits, relatively short straw, drooping long-bearded heads, the brittle floral axis already referred to, and big seeds such as would catch the eye of an observant and hungry Neolithic man. But it shows another interesting quality, namely, variability; for Mr. Aaronsohn found a considerable number of different forms. The interest of that is obvious, for it has doubtless been by taking advantage of the variations that have cropped up in the course of many millennia that man has been able to establish one successful race after another on his fields. For thousands of years, however, the cultivation must have been very haphazard. Many varieties grew together in the field, though not mixing very much after self-pollination was established, and the husbandman chose a mingled lot of good ears to furnish seed for the next sowing. Virgil refers in the Georgics to the gathering of the largest and fullest ears in order to prevent degeneration. This was selection, but it was somewhat rough and ready.

The Emergence of Modern Wheat

In the first quarter of the nineteenth century, however, a great step was taken, namely, the beginning of the deliberate selection of individual ears and a segregation of the progeny. According to Professor De Vries, the first to recognise that the wheat-field contained a medley of different varieties was Lagasca, a Spanish Professor of botany, who gave the hint to Colonel Le Couteur in Jersey, with the result that a number of varieties were sifted apart, and a particularly good one, "Talavera de Bellevue," was placed on the market. About the same time the method of isolation and segregate-cultivation was taken up by Patrick Sheriff, of Haddington in Scotland, whose achievements are inestimable. Another contributor was Vilmorin, who introduced what he called the "amelioration of the race," or the continued singling out of the best representatives of a pure strain. The isolating of individual promising variations and making each the beginning of a pure line has been the prevalent method of recent years, and has led to remarkable results in the hands of investigators like Nilsson-Ehle in Sweden and Hays in Minnesota.

The Story of Marquis Wheat

But the modern method will become clearer if we take the particular case dealt with in most detail by Professor Buller—the famous Marquis Wheat, which was of so much importance in assisting the Allies to overcome the food crisis in the darkest period of the war. In 1917 upwards of 250,000,000 bushels of this variety were raised in North America, and in 1918 upwards of 300,000,000 bushels; yet the whole originated from a single grain planted in an experimental plot at Ottawa by Dr. Charles E. Saunders so recently as the spring of 1903. Marquis

is a hard, red, spring wheat with excellent milling and baking qualities; it is now the dominant spring wheat in Canada and the United States; it is very prolific and ripens early; it has enormously increased the wealth of the world in the last ten years.

Now, the point is that Marquis was discovered deliberately in the course of precise searching for a variety of wheat well suited for Western Canada. Its parent on the male side was the mid-European Red Fife, a valuable variety with a very interesting history; its parent on the female side was rather a nondescript, not pure-bred, called Hard Red Calcutta that was imported from India into Canada some thirty years ago. It had the good quality of early ripening, but linked with this were undesirable qualities such as poor yield, very short straw, and the scattering of the grains from their glumes when ripe. So the inheritance from the maternal side was not brilliant. The father seems to have been the source of most of Marquis's virtues, for Red Fife was, and still is, a first-class cereal which first "established the reputation of the Dominion for the production of high-grade wheat with excellent milling and baking qualities."

One of its kernels was conveyed in a cargo of winter wheat, via the Baltic and the North Sea, from Danzig to Glasgow; a sample of the cargo containing the kernel in question was procured by someone at the Scottish port; this sample was sent to David Fife at his farm in Ontario about the year 1842; this single kernel germinated and produced a plant with three heads; the kernels of these three heads, when sown the next year, gave rise to the wheat which became known as Red Fife.

So much for the parents of Marquis; but how was Marquis discovered? The result of the cross was a mixture of types, nearly a hundred varieties altogether (besides strains within the varieties), and it was by the system-

atic testing of these that Dr. Saunders hit upon Marquis. He worked steadily through the material, "studying head after head, and selecting out as many different and promising ones as he could find." Each head selected was propagated, most of the results were rejected, but finally Marquis emerged, rich in constructive possibilities, probably the most valuable food-plant in the world. "The first crop of the wheat that was destined within a dozen years to overtax the mightiest elevators in the land was stored away in the winter of 1904–1905 in a paper packet no larger than an envelope." Well may we speak of the romance of the wheat.

XLIV

TOWARDS SOCIALITY

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It is interesting to try to discover what one may call the main trends of organic evolution—lines of movement in a definite direction exhibited independently by unrelated groups. Thus in different phyla there is a very obvious trend in the direction of improving the nervous system, another in substituting sexual for asexual reproduction, another towards viviparity, another towards the conquest of the dry land, and so on. Has not one of these big trends been in the direction of sociality—the combination or association of kindred creatures in various approaches to corporate unity?

Aggregates and Integrates

In the course of evolution there have certainly been many important aggregations and integrations in Nature. Corpuscles formed atoms, and atoms molecules, and molecules groups of molecules, and groups of molecules may have integrated into living matter. Ages passed, and there were finely finished minute organisms, the early Protozoa and Protophyta, most of which remained, however, in a non-cellular phase of being. Ages passed, and from among these non-cellular (or unicellular) creatures there was a gradual emergence of organisms with many-celled bodies, and of the origin of these we get some hints from certain Protozoa and Protophyta of to-day,

which are in the habit of forming loose colonies with little or no division of labour. Alongside of these inorganic and organic aggregations and integrations there have been of course, processes of an opposite tendency. There have been dissociations and dehydrations and all sorts of inorganic weatherings: the crystal is slowly dissolved, and the mountains flow into the sea. Likewise the organic castle-of-cards is always falling to pieces; there is a see-saw of katabolism and anabolism. "And so, from hour to hour, we ripe and ripe, and then, from hour to hour, we rot and rot, and thereby hangs a tale." But after allowing for all the disintegrating and running down, we are surely within our rights in saying that there have been momentous aggregations and integrations in the past—that there is a cosmic tendency or trend in this direction. This is especially true of the realm of organisms, where natural death itself—the most universal of all vital disintegrations—is sometimes successfully evaded.

Colonial Creatures

Postulating the power of growing, itself dependent on the organism's fundamental dynamic quality of accumulating energy acceleratively up to a limit, we can understand the disposal of surplus material, so as to form various kinds of colonial animals, especially in the sea. By budding, and by division of units without subsequent separation, there have arisen such aggregates of individuals as we see in zoophytes, sea-fans, sea-pens and reef-corals, and, at higher grades of organization, in Polyzoa, Cephalodiscus and the compound tunicates, both sedentary and free-swimming. Of great interest are those multitudinous colonies like the Portuguese Man-of-War, in which there are several different kinds of individuals showing division of labour, and all so integrated that the colony acts as one creature. This is the climax of what

we may venture to call the social trend on the ***vegetative*** tack of evolution. We cannot follow this line further, but it is important to notice that it was particularly well-suited for easy-going marine conditions, whereas another architectonic way of disposing of abundant growth-material—namely, the establishment of a bilateral segmented body—was well suited to lead the way to the conquest of the earth. It is interesting to reflect that the acquisition of the kind of body-architecture familiar in the earthworm, with its bilaterality and its segments, its dorsal and ventral surfaces, its head-end and tail-end, was the beginning of our knowing our right hand from our left.

Gregarious Life

A non-cellular organism multiplies by division, budding and spore-forming, and its daughter-units separate off; if they remained coherent there would be the beginning of a multicellular body, as we see in Volvox, a beautiful green ball of 1,000–10,000 cells, sometimes found rotating in the water of pond or canal. Many a simple multicellular organism disposes of surplus material in the form of buds, which separate off, as we see in the fresh-water Hydra; if they remained coherent there would be the beginning of a colony, as in most zoophytes. Similarly, if the members of a physically discontinuous family remained together gregariously instead of separating to live independent lives, there would be the beginning of another kind of aggregate, the big family, illustrated by a humble-bee's nest early in the year—the big family which passes almost insensibly into a community or a herd. From a large family of ants all the children of one mother, it is but a step to families with grandchildren as well as children, to families of several generations, to a combination of several consanguineous families living co-operatively, to a community of blood relations showing considerable

division of labour, and this is almost a society. The true animal society is a group of kindred individuals which can act coherently and harmoniously as a unity, which has a corporate life, which is more than the sum of its parts. An ant-hill, a bee-hive, a rookery, a beaver village may serve for illustration. The mere living together of a multitude, like mites in the great cavern of a cheese, does not constitute a society; there must be some corporate life. When ants go on a slave-making expedition, when beavers unite their efforts to make a canal through a big island in the middle of a river, when rooks combine against a hawk, there is the distinctive social note of *esprit de corps*.

Animal Societies

When we study herds and societies of big-brained animals, evolved on an *intelligent* basis, we feel more or less at home. In the merry company of monkeys, sometimes uniting in common adventure, in the herds of horses or the pack of wolves, in the beaver-village or the city of viscachas, among the rooks, cranes and parrots, there is an approach to the human. Sometimes there are conventions which must not be disobeyed; sometimes there is combination in defence, attack and enterprise; there is often the suggestion of social tissue which does not appear foreign to what we know in mankind. There is no doubt as to a certain measure of pre-human sociality, and among gregarious birds and mammals it is of a type that we can more or less readily understand.

Instinctive Societies

On the other hand, animal societies on the *instinctive* line of evolution (as among ants, bees and wasps) seem far away from us; we cannot breathe their atmosphere. Let us take a few glimpses. The division of labour is often carried to an absurd length. Thus some individuals

among the honey-ants, which Dr. McCook described from the "Garden of the Gods" in Colorado, are fed by their fellows until they become mere animated honey-pots, which are tapped later on. While the Umbrella Ant workers are busy in the Brazilian forest cutting discs from the leaves, some of their fellows, with enormously large heads, simply walk about looking on; they have been called "worker-majors," but no one knows what they do, unless their big heads serve as buffers against onslaughts on the workers. How quaint is the habit that some termites, or white ants, have of keeping wingless reproductive members in reserve, complementary kings and queens which replace the functional royal pair if need arises!

Similarly, when we consider the subtlety of many of the social operations in these instinctive societies—the keeping of slaves on which the masters become dependent not only for food but for the utilisation of it, the organising of raids and the engagement in battles, the using of the offspring to supply silk for binding leaves together as in the tailor ants or to supply drops of elixir as in some kinds of wasps, the domestication of other insects, the toleration of guests and pets, and, as everyone knows, there is a long list of these extraordinary doings, we seem to be in a different world, more like a caricature than a prototype of human societies. In these instinctive societies the individual life seems to count for very little; there is a fanaticism of self-subordination; large numbers often remain non-reproductive. Many an ant-hill is a grim warning of the dangers of extreme state-socialism, but as to its success in the struggle for existence there is no manner of doubt.

Advantages of Sociality

As there are many instances of animal societies at various levels, there must be great advantages in the

gregarious mode of life. Many small creatures, individually contemptible, become safe or indeed irresistible when united in large corporate bodies. The Argentine ant has in recent years conquered most of the fauna of Madeira. Several members of a community working together in food-getting may accomplish what would baffle single individuals, as when several ants unite to drag a big spider to the nest, or when wolves surround their prey, or pelicans form a living seine-net for fish. From simple advantages such as economising heat when large numbers huddle together, to subtle advantages such as lessening strain, when one wild goose replaces another as leader of the flying phalanx, there are numerous obvious advantages in the social mode of life. But it is necessary to go further. The division of labour, which is often associated with communal life, makes the life of the species more effective, as is plain enough from the simplest case—which is independent of societies altogether—the division of labour between two parents. It is almost like a diagram when the hen-bird sits close and the male hunts for food. When the division of labour becomes specialised in animal societies, as among ants and termites, there is the same advantageousness, but there is more. The implied relation of mutual dependence between the members of the community will tend to foster the kin-sympathy and other psychical bonds which originally made the community possible. As the society gains in stability there will be opportunity for experiment, there will be the beginning of a tradition and of external registration in permanent products, there will be time for such luxuries as fine edifices and play. A milieu will be evolved in which wits will thrive. In the struggle for existence, which includes all the answers-back that individual organisms make to environing difficulties and limitations, endeavours in the way of co-operation and sociality are evidently rewarded just as are efforts in the direction of

keener competition, and perhaps we may say that there is a good deal of secondary benefit, beyond survival, thrown in to reward those inclined to be social rather than individualistic. The social milieu is one in which there is a good chance, to say the least, for the improvement of wits and the growth of kindliness, not to speak of the appearance of admirable achievements like the wasp's nest, the honey-comb, the termitary and the beaver-dam. The society always comes as a shield between the individual and the severity of Nature's sifting. This is all too plain in human societies.

Why Is Not Sociality More Widespread?

If the social way of life has all the advantages alleged, the question naturally arises why it has not been adopted by a larger number of types. The answer is to be found in certain pre-conditions of sociality—(1) There must be some degree of prolific reproduction. Very slowly breeding animals, unless also very long-lived, will not readily form societies. (2) There must be some fineness of brain, in the direction both of wits and sympathy; green-flies are prolific enough to be social, but they have not got the requisite brains. (3) There are certain habits of life which preclude sociality. Thus, while spiders are clever enough to be social, and there are two or three social species, their way of getting a living is intrinsically individualistic. One does not expect anglers to fish together in an eleven. Thus we see that while the social way of life is very advantageous and brings many secondary rewards, it is far from being open to all. It is only for the elect.

XLV

INBREEDING AND OUTBREEDING

INBREEDING AND OUTBREEDING

THERE can be no doubt as to the evolutionary importance of inbreeding and outbreeding in the rise and progress of races of plants, animals and men. Everyone knows that many primitive peoples were very strict in enforcing marriage outside the family or clan (exogamy), and while the taboo against consanguineous matings cannot have had at that time a biological basis, there must have been behind it some definite apprehension of the evil effects of inbreeding. On the other hand, in certain countries (such as Egypt and Greece) and at certain times (*e.g.* at a high tide of national civilisation), close inbreeding or endogamy was sometimes practised within castes, and with this there must have been associated a more or less conscious conviction that to gain social and cultural advantages it was worth running some biological risks. Many years ago Reibmayr wrote a scholarly book on the alternation of inbreeding and outbreeding in the history of peoples—a biologically interesting idea.

Are Cousin-Marriages Harmful?

In a monograph on the subject (*Inbreeding and Outbreeding, 1920*) Drs. Edward M. East and Donald F. Jones have tackled, in the light of modern biology, three questions of great theoretical and practical moment: (1) "Do marriages between near relatives, wholly by reason

of their consanguinity, regardless of the inheritance received, affect the offspring adversely? (2) Are consanguineous marriages harmful through the operation of the laws of heredity? and (3) Are hereditary differences in the human race transmitted in such a manner as to make matings between markedly different peoples desirable or undesirable, either from the standpoint of the civic worth of the individual or the stamina of the population as a whole?"

If a thoughtful breeder of stock, who is unprejudiced by biological literature, be asked for his opinion in regard to close mating, he will probably answer that it has its advantages and its disadvantages. It is advantageous, because, if it is accompanied by the usual judicious selection and elimination, it fixes desirable characters and leads towards a uniform and stable herd. It is disadvantageous because it is apt to lead to reduction of vigour, resisting power, fecundity, and even size. But if the breeder is asked, furthermore, whether these disadvantageous consequences are actually induced by the close-breeding as such, or are simply brought to light and accentuated by it, he will probably answer that he does not go into things so minutely as all that.

Experiments on Inbreeding

Yet it is this second question that is vital, and the answer to it has been furnished by experiment. For it has been proved that the close inbreeding of fine stock, associated with the usual selection and elimination, may be persisted in for several generations without any undesirable consequences. Many fine breeds of animals and races of plants have had very close inbreeding at their beginnings; and there seems to be habitual endogamy among bees and ants. Furthermore, it has been shown that the direct result of persistent inbreeding is to segre-

gate or isolate within the stock a number of true-breeding strains of similar individuals. If there were, to begin with, in the inheritance of the herd, say, four distinct hereditary factors relative to a particular character, such as the colour of the pelage, then the automatic effect of the inbreeding will be to isolate four types, pure, as regards that particular character. This is a simple theorem in Mendelism. But some of the characters which thus become isolated may be undesirable "recessives," seldom seen under ordinary circumstances because they are hidden by their "dominant" counterparts. The undesirable albinism, likely to be kept under in conditions of exogamy, is isolated and brought to light in endogamy. "These recessives are the 'corrupt fruit' which give a bad name to inbreeding, for they are often—very often—undesirable characteristics."

Close Inbreeding Detects Taints

This detection of undesirable features by close-mating may be utilised by the breeder who knows his business. When naturally cross-fertilised organisms are inbred, there is sometimes an advance, but there is at least as often a disappointing retrogression. Thus, in the case of grain, there may be a reduction of productivity to perhaps over a half of what it was; in maize there is often a marked reduction in size and rate of growth. Now, this lowering of the average seems to be due to an outcrop of undesirable characters which were in the general inheritance of the stock (sometimes because of its multiple origin from ancestors of diverse merits), but were kept out of sight by more favourable characters which dominated them. "Inbreeding tore aside the mask, and the unfavourable characters were shown up in all their weakness, to stand or fall on their own merits." But if stern elimination is practised and the "isolated" types with unde-

sirable characters are got rid of, the stock will be the better of its purgation, and the mysterious quality of "vigour" can be regained by outbreeding.

As to this "vigour," Darwin was strongly of opinion that the gain in constitution derived from an occasional crossing was a more important biological fact than the loss that often followed close breeding, and modern experimenters have confirmed his shrewd judgment. Both for animals and plants, the outbreeding often has advantageous results like those that reward a notable improvement in nurture. If the crossing be successful at all (for there is a seamy side leading to weaklings and sterility), there is increase in "vigour," resisting power, size and other good qualities. The reason for this frequently observed "hybrid vigour" is probably to be found in the pooling of diverse hereditary resources of good quality, not in some vague physiological stimulus to the offspring. The crossing makes it more likely that a minus on one side may be made good by a plus on the other, or that desirable dominants may strengthen one another's hands. We have just mentioned sterility, which remains a baffling fact, not less puzzling when we know that both inbreeding and outbreeding may lead to it. Drs. East and Jones suggest that there are two quite different kinds of sterility of diverse origin: (1) Inbreeding tends to sort out homogeneous pure strains, and in this sifting out the ability to reproduce may be lost; (2) outbreeding may bring together two germ-cells too incompatible to allow of a continuance of the process of germ-cell making. Thus, the number of chromosomes in the two parents (*e.g.* horse and ass) may be too discrepant. But these are deep waters.

Inbreeding Not Harmful in Itself

When the same undesirable qualities occur on both sides of the house, inbreeding tends to diffuse and exag-

gerate them. Moreover, inbreeding tends to expose, and, unaccompanied by stringent selection, to fix detrimental recessive traits which were kept unexpressed in circumstances of outbreeding. Nevertheless, the result of modern experimenting is clear, that "inbreeding is not in itself harmful; whatever effect it may have is due wholly to the inheritance received." When the inheritance is on the whole good, "inbreeding is the surest means of establishing families which as a whole are of high value to the community."

Outbreeding Promotes Variability

A broad survey of the realm of organisms discloses a number of great trends of evolution, such as getting out of the water, substituting sexual for asexual reproduction, and establishing viviparity (flowering plants and mammals). One of these great trends of evolution is towards the securing of cross-fertilisation, though the range of the crossing varies within wide limits. Parthenogenesis has been tried and self-fertilisation has been tried, but some form of cross-fertilisation has prevailed. There must be some deep reason justifying this, and the survival value of cross-fertilisation lies in the fact that it promotes variability. It brings about a greater variety of raw material on which selective agencies can work. Similarly, for the wider ranges of cross-fertilisation which we call outbreeding, the general result of experiment shows that this is valuable in promoting variability, both in the way of new patterns and new vigour. It is not from within inbred castes but from outbreeding in the general population that most of the men of outstanding ability have come. And if it should be urged that the same argument would lead one to expect great things from the mating of widely separated types, such as Caucasian and Mongolian, the answer is that "such unions tend to

break apart series of character-complexes which through years of selection have proved to be compatible with each other and with the persistence of the race under the environment to which it has been subjected." "The changes are too few and the time required is too great for the proper recombinations, making for inherent capacity, to occur." On the other hand, the intermingling of peoples *somewhat* unlike genetically, but not *too* unlike, has been a frequent factor in progress in the past, and must be looked forward to in the future. Always provided, of course, that "the ingredients in the Melting Pot be sound at the beginning, for one does not improve the amalgam by putting in dross." All this has to be applied to Ireland and America, Britain and the Balkans alike.

XLVI

THE HUMAN HAND

THE HUMAN HAND

FEW people know nowadays of "*Bell on the Hand*," but it was a famous book about the middle of last century and it is good reading still. There is abundant entertainment in it that has not much to do with the hand, such as Harvey's story of the noble youth who had an opening on the side of his chest through which, as a great privilege, Charles I. was allowed to behold and touch the heart. The author, Sir Charles Bell, was a distinguished anatomist, who established the momentous distinction between motor and sensory nerves, and the object of his "Bridgewater Treatise" was to illustrate from the perfections of the hand as an instrument the wisdom of the Creator. This was the familiar "transcendent inference" of the argument from design. Paley's form of the argument has ceased to appeal, for Darwin showed, in a general way at least, how the fitnesses of the hand have been gradually evolved by the secular sifting of successive new departures. Yet perhaps we are not wrong in sharing Sir Charles Bell's admiration for the hand, for it is a masterpiece to which untold generations of organisms have contributed with a remarkable combination of plasticity and retentiveness, "testing all things and holding fast that which is good." Even apart from any "transcendent inference" the hand is worthy of our admiration, most of all when considered as the outcome of a long evolutionary process; and so we turn from Sir Charles Bell's book of 1833 to Professor Wood Jones's book of 1920 (*The Principles of Anatomy as seen in the Hand.*)

A Generalised Hand

Man with his nimble brain can do so many different things with his hand that no one can be surprised at the widespread idea that it is a very highly evolved instrument. This is true in a sense, but what Professor Wood Jones insists upon is that the human hand is very *generalised.* That is evident at a glance, when we compare it with a highly specialised hand like that of a bat or of a mole, but it admits of detailed proof. Thus the number of digits is five, which is the primitive number, for although the horse has only a single complete digit on each limb, we know that it is descended from ancestors with five, and although some of the extinct aquatic Ichthyosaurs had six or more digits, there seems no doubt that this condition was derived (*e.g.*, by splitting of the third finger) from the pentadactyl type in most terrestrial reptiles. Almost the only specialisation of the human hand is in the mobility of the opposable thumb, and that is practically a general character of monkeys and apes. "The human condition of complete pentadactylism is," according to Professor Wood Jones, "a feature which stamps this part of man's anatomy with the hall mark of primitiveness." What is true of the number of the digits holds good also in regard to the proportions of the fingers, except that there is in some people a marked elongation of the index, and in regard to the finger-joint-formula. Man's foot is extremely specialised, man's hand is very generalised.

In the palm of the hand or metacarpal region there is a slight specialisation, namely, the stoutness of the bone which bears the index finger, and this our authority interprets as "definitely related to the use of the index finger as a companion to the mobile thumb in the act of picking up objects and grasping them." Similarly, man's wrist or carpus, though extremely primitive, has the peculiarity that one of its eight little bones—the *os centrale*—has

disappeared as a separate entity. Its fusion with one of its neighbours, the scaphoid, probably gives greater stability at the base of the important index finger. It is an eloquent fact that in the gorilla and chimpanzee, where the index finger has also attained to some importance, the fate of the *os centrale* has been the same as in man—it has fused with the scaphoid. In the orang and gibbon and in most monkeys there is a separate *os centrale*, as in mammals generally. This little bone is a straw which shows how the evolution wind has blown.

The Lines on the Hand

Many credulous people are much interested in the lines on the palm of the hand, and are intimately acquainted with the individual peculiarities of their "line of heart," "line of head," "line of life," and the others. But the lines have also a biological interest. They indicate lines of comparative skin rest, where the skin is anchored to the underlying tissues; they are crease lines suited to give the greatest freedom of movement to the joints. They must have been established very long ago, for there is a general human pattern of lines, quite different from that of apes or monkeys, and the main creases appear very early in antenatal life before there is any movement of the hand. But the other side of scientific palmistry is not less interesting, that within the limits of a general human pattern there is great individual variability in the finer ramifications, and likewise great individual modifiability according to the work we do with our hands, or the games we play.

Finger-Prints

Entirely different, of course, from the flexure lines we have just spoken of are the papillary ridges. These are delicate thickenings of epidermis separated by furrows;

they are disposed in regular patterns of parallel lines, concentric circles, and close spirals; they show the openings of sweat-glands along the crest of the ridge. The patterns formed by the papillary ridges do not change throughout life; they are established before the ante-natal chapter is half over; they differ somewhat in different races and they are so strikingly individual that their practical importance as a means of identification, first pointed out by Dr. Henry Faulds in 1880 and afterwards emphasised by Galton, is nowadays generally recognised. Professor Wood Jones writes.

> The print of any individual finger-tip may be recognized with certainty among thousands of such prints, and when we remember that each of the ten digits shows its own peculiar pattern and its own distinctive minutiæ, the chance of coincidence in the patterns of any two individuals when the print of more than one finger is examined is practically negligible.

It seems likely, however, that the patterns are in some measure hereditary characters. As to their significance, their wide occurrence among mammals with the power of gripping surfaces and objects, points to the conclusion that they ensure "a firm, precise, and sensitive apposition."

Nails

There is much that is biologically interesting in the nails which protect the sensitive tip of the digit, serve for scratching, and increase certain kinds of grip. The most primitive nails are those of some amphibians, and they are flat plaques; so the question rises whether our nails represent a retention of a very primitive condition or a flattening of the common arched claws of most mammals. They arise in the individual as cornifications of the epidermis

below the surface, and the covering which originally hides them persists as the irregular margin of transparent skin at their base and the "sole pad" beneath their free edge. They grow throughout life, the exposed area being normally renewed about every eighty-seven to one hundred and twelve days. They are to some extent indices of health, and Professor Wood Jones favours the view that the familiar little white spots are partly due to worry! Our own experience is more commonplace.

The Hand in Evolution

The muscles and tendons, the connective tissues and blood-vessels of the hand are just as interesting as the bones and surface-characters, but they are not so readily dealt with. On the whole, they bear out the thesis that man's hand is generalised. As Aristotle, Galen, Sir Charles Bell, and Professor Wood Jones have all recognised in their several ways, the excellence of the human hand is in being a generalised tool which the fertile brain can use in a hundred different ways. "It is not the hand which is perfect, but the whole nervous mechanism by which movements of the hand are evoked, co-ordinated, and controlled." But this, again, requires to be corrected by two considerations: first that a mobile testing hand, relieved from doing duty as an organ of support, as Professor Wood Jones made so clear in his *Arboreal Man* (1916) was closely correlated with the development of the cerebral cortex, and, secondly, that as the muzzle region of the head became less marked and less utilised for testing things by actual contact, the hand became increasingly a sense-organ. In enabling man to test the qualities of his surroundings—texture, shape, sharpness, dimensions, weight, pressure, vibrations and temperature—the hand has played an incalculably important part. In spite of its generalised fundamental features, man's hand is, as

regards its sensory nerve-endings, more specialised than in any other creature. It has been one of the great gateways of knowledge, and in manipulative art it has been one of the chief instruments of the soul.

XLVII

MAN'S PLACE IN NATURE

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ACCORDING to Dr. John Lightfoot, an eminent Hebrew scholar in his day, and likewise Vice-Chancellor of the University of Cambridge, man was created by the Trinity on October 25, 4004 B.C., at nine o'clock in the morning. According to Professor Sir Arthur Keith, Conservator of the Hunterian Museum, "man had reached the human standard in size of brain by the commencement of the Pliocene period . . . that is to say, about one million years ago." In all probability the truth is between these extremes, but nearer Sir Arthur Keith's estimate than Dr. Lightfoot's. In his interesting and challenging book, *Man and the Attainment of Immortality* (1922) Professor James Young Simpson writes:

> When we realise that flints of indubitable human workmanship are found in the drift gravel of the Somme at a distance of 100 feet above the present level of the river, and then consider how slowly the river is being lowered by erosion, we begin to have some sense of the vast period that has elapsed since man first dropped these implements by the water's edge, and are ready to believe that 400,004 B.C. is a more approximate date to his appearance than 4004.

What is certain is that man of the modern type appeared on the scene very long ago, and there were tentative men before that.

Man's Solidarity with Mammals

But there is, of course, an even deeper difference between Dr. Lightfoot's view and Sir Arthur Keith's. According to the former, man was created one morning by the Trinity, which means that he arose in a fashion which cannot be described in scientific terms. According to the modern view, man arose "naturally," a mutation or transilient variation in all probability, yet continuous with a pre-human ancestry. Man was solidary with a Simian stock, and arose from Primate parents who begat him; and there is no reason why he should be ashamed of his poor relations. If there is great excellence in him—the achievement, there must have been the right stuff in those by whom it was achieved.

Man's Ancestry

No naturalist supposes that the human stock was derived from any existing ape. That is out of the question. But the facts point to the divergence of mankind from a stock which diverged on another line to give rise to the larger Anthropoid Apes—the Orang, the Gorilla, the Chimpanzee, and some extinct forms. The human branch and the ape branch sprang from a stem common to them both; they are collaterals.

Another important fact is what we might call the successive segregating of the more progressive. Very long ago—perhaps two million years ago—in the Eocene Ages, there was a stock of primitive, somewhat generalised, monkeys. For the time they occupied the top of the tree—the genealogical tree. But first of all, there was a separating off of the branch whose twigs are the New World Monkeys. Later on the same thing happened for the Old World Monkeys. That left an Anthropoid main stem with a vigorous growing point. But the segregating process went on. Another branch diverged—that of the

smaller Anthropoid Apes, the Gibbon, the Siamang, and some extinct forms. Then came the separating off of the larger Anthropoid Apes, leaving the main stem Humanoid. But even then the segregating process continued, for there diverged Pithecanthropus the Erect, the slouching men of Neanderthal, and the type represented by the Piltdown skull, leaving at last the purified main stem—the modern man type—from which have diverged Africans, Australians, Mongolians, and Europeans. The point is that even the Neanderthalers do not seem to have been our ancestors but only a collateral species. They probably represent a blind alley in evolution except in so far as their virtues may have been continued by crossing with *Homo sapiens.*

It is not to be supposed that all the fossil remains of man are off the main stem, for that would leave the main stem an unknown quantity; but there appears to be general agreement among experts that Neanderthal man, for instance, was no ancestor of ours. He was one of the early tentative men, who shared in the struggle but did not inherit the promises. Nor must we allow ourselves to confuse the segregation of the less promiseful with the ordinary eliminative operation of Natural Selection. The monkeys diverged, leaving the main line the better for their absence, but there was no failure on their part. They have evolved successfully on a line of their own. Similarly with the Anthropoid Apes. Though there are extinct genera of apes, as among monkeys, the Anthropoids have held their own, and they have many admirable qualities. In the case of the Neanderthalers there was divergence from the main stem, but there was also, unluckily, extinction—as a distinct race at any rate.

Factors in Man's Emergence

As to the factors leading to the emergence of the human type, we remain immensely ignorant. But we must not

be impatient, for evolutionary inquiry is still very young. It is probable that an arboreal apprenticeship on the part of our pre-human ancestors counted for much. It was a great step when the hand ceased to be a supporting limb and became a free hand—all the more valuable because it remained generalised, able to do all sorts of things. The emancipation of the hand, which made it available as a food-capturing organ, allowed of the reduction of the muzzle; and that meant a possibility of great increase in the cranial region or brain-case. No doubt there was a correlated advance in the development of the cortex of the fore-brain, so that it became easier for the animal to make judgments in jumping from branch to branch, to establish associations between endeavours and results, and to store memories. Germinal variations in the direction of a more highly developed cerebral cortex would be approved of in the everyday sifting and would become part of the racial inheritance; and thus was progress made.

Another factor was the capacity for sociality, a capacity which was pre-human in origin, but came to its own increasingly as the Humanoid brain grew finer, or, to put it in another way, as the psychical side became more dominant. As was said wisely long ago: "Man did not make society; but society made man."

Some authorities rebut the speculation that our pre-human ancestors served an arboreal apprenticeship, but the theory has much to commend it. When the Humanoids, with their free hands, their enlarged cerebral cortex or neopallium, and their capacity for co-operative action, had resources sufficient to enable them to stand up to to Carnivores and other enemies, they left the trees and became once more terrestrial—and *Men.* But they were bipeds now, save when babyhood recapitulates the past, or when some shock or degeneration involves a slipping down the rungs of the steep ladder of evolution. With the upright attitude there is probably to be associated

the further evolution of the voice; and when language began, as a means of social intercourse and mutual corroboration, sociality would grow apace. All these processes work in spirals: sociality favours variations in the direction of language, but language makes progress in sociality more practicable. Evolution works in virtuous circles.

The Ascent of Man

At different times in the course of evolution there have been differences in the sieves that determined survival. There has been an evolution of sieves as well as of the new material submitted for sifting. Usually the sifting has had reference to the qualities of importance in the quest of food—and we have not yet got beyond that. But sometimes the emphasis was laid on fertility and at other times on the strength or swiftness which made it possible for an animal to baffle its enemies. More and more as we ascend the series the decisive factor is to be found in wits or cunning rather than in strength or fertility. One of the many good points in Professor J. Y. Simpson's book, *Man and the Attainment of Immortality* (1922), is the insistence on the changes, throughout the ages, in the criteria determining survival. It is a good point as long as it is not over-emphasised. But it must be borne in mind that on the whole the fundamental criteria persist—though with varying emphasis—all along the line and all the time. There must always be success in the quest for food; there must always be health (we are excluding parasites from consideration); there must always be ability to hold the gate against enemies and keep a place in the sun; there must always be a birth-rate sufficient to counteract the death-rate.

Yet when all this is said, we feel that for primitive man, with his growing brain and vocabulary, the next most essential quality was a strong kin-instinct and a capacity

for team-work. What was all-important, given the big brain and language, was a willingness to subordinate self in playing the game. In short, man's survival depended largely on ethical qualities. In the evolution of these, the prolonged infancy of the offspring doubtless played an important part. As Lucretius said long ago, "Children by their caresses broke down the haughty temper of their parents."

It has often been said that such subtle human qualities as musical talent cannot be accounted for along the lines of the Darwinian theory, that is by the natural sifting of new departures. But we doubt if there is any great difficulty here. In the first place, no one is inclined to postulate any special spiritual influx to account for the evolution of the notable musical talent of birds. It has its survival-value in connection with mating and as an expression of very vital emotion. In the second place, there is no doubt as to the integrative value of music in the social endeavours of mankind. Furthermore, it is true throughout all organic evolution that a new departure, not in itself of immediate utilitarian significance, may be correlated with some more obviously justifiable variation and be carried in the wake of this into safety. It is easy to imagine, if we cannot prove, that musical mutants might survive, to start with, not because they were musical, but for more commonplace reasons.

What happened eventually—if we dare use such a word in reference to a race so relatively young as mankind—was that man became conscious of his own evolution and began to take a hand in determining its trend. Many a time, we believe, wide-awake organisms have been active agents in their own evolution, *e.g.*, in choosing the environment that suited them; but man's rational, or more or less rational, selection is a new feature that has made all things new. Persistently, though with chequered success, he has been eliminating the factors that make for disease, dis-

harmony, and distress. But now there is in his eyes a more positive ideal—the ideal of fostering health, harmony, and happiness, so that in this world there may come about an all-round realisation of the true, the beautiful, and the good. Thus man's life as a social organism will become increasingly a satisfaction in itself. *In hoc signo laboramus.*

XLVIII

THE HUB OF CREATION

THE HUB OF CREATION

If we can imagine Martian naturalists visiting the earth before the emergence of any of the Hominidæ (Man and tentative men), we can also imagine that they would be greatly interested. The world is full of artistic masterpieces, fascinating ingenuities of organisation, and intricate interweavings that make a pattern. Almost everywhere the Martians would find order and fitness; almost everywhere the Martians might hear snatches at least of "an onward-advancing melody," as the philosopher Lotze phrased it. The earth without man is like a cathedral without spire or tower—but a cathedral. It is full of wonders that angels might delight to look into.

Man as Crown

What gives the world beauty and scientific interest is not the presence of man, for we can imagine the visit of the Martian explorers to a beautiful and interesting pre-Tertiary earth; and, besides, it is idle to pretend that there is not some infra-human delight in beautiful sights and sounds, that there is not some infra-human regional survey! But the important fact is that when man emerged, Animate Nature gained a new significance. In him the mind that had been struggling through all "the spires of form" found some measure of emancipation.

The Logos became articulate in a new language. And as man began to understand Nature and to see himself objectively as her child, he also came to see in a dim way that he was the result of ages of groaning and travailing, that he was no episodic phenomenon in a long chapter of accidents, but a climax towards which thousands of events had conspired. We do not mean that man has not a long way to go yet; but we adhere to the philosophy which regards man as a flower that illumines the whole plant—even the roots which go deeply into the ground. The broadly-laid foundations—all the balance and intricacy of Nature—have made man possible; and it looks as if he were the outcome of a well-considered plan.

Man "with Worlds to Attend Him"

We make the philosophical postulate that man, as the finest expression of Nature's evolution, throws light on all his antecedents.

We find scientific evidence of a succession of preparations that made higher organisms, and eventually man, possible; we see a balance established throughout ages which made a lofty superstructure stable; we discern a multitude of little circumstances that make the earth what one might call "friendly" to man. The ancillary creatures were not exactly created for man, but they are parts of a coherent system of which man is at present the highest expression.

Following a scheme which Sir Ray Lankester suggested long ago, we wish to illustrate the manifold practical interrelations which have been established between man and animals. The subject is almost inexhaustible, but there is often an advantage in a bird's-eye view. It will be seen at a glance that some of the intersections between man's vital circle and those of other creatures are very ancient, and others very modern. They are always changing.

Edible Animals

The first procession is that of animals captured for food, and it is a motley crowd. Deer and antelopes, rabbits and hares, pigeons and partridges, frogs from France, and all the food-fishes of the sea and the fresh waters. Squids from the Mediterranean, snails from Italy, cockles and mussels, oysters and clams from our own shores. Crabs and lobsters, shrimps and prawns; locusts served with wild honey, juicy grubs from the palm trees, and white ants for the Hottentots. Once a year the Samoans have a feast of headless palolo-worms which make the sea like thick vermicelli soup. The roe of the sea-urchin is a common Mediterranean delicacy, and the sea-cucumbers or *bêche-de-mer* form an important commodity in the Far East. Characteristically enough, the Japanese eat dried jellyfish, but no one has been able to make a meal of sponges. The nummulites, common as fossils in some parts of Egypt, are called "Pharaoh's bean," but that is just a little joke.

Animal products

The second procession is that of animals captured not for the sake of food directly furnished by their flesh, but for the sake of other products, which are sometimes edible. Here we have the baleen whales with their whalebone plates and their oil, the elephants with their ivory tusks, the wild asses whose skins are made into drumheads, the beavers yielding the sweet-scented castoreum and the hats of long ago, scores of mammals giving up fur and hide. Here come feathers for arrows and the angler's flies, for the savage's head-dress and the lady's hat; the crocodiles give us leather bags and the turtles combs; inedible fishes yield glue and fertilisers; the cowries are for money and the big oysters for mother-of-

pearl; the cantharid beetles make blisters for our skin. This procession would fill the whole page if we let it.

The third procession is a short one, consisting of those animals that man has more or less domesticated because of their direct or indirect utility. Here come dog and horse, sheep and cattle, goats and reindeer, pigeons and poultry, ostriches and pheasants, silk-moths and honey-bees, and a few more besides.

The Scavengers

The fourth procession consists of those creatures that favour man's operations. Here are the earthworms that have made the fertile soil and the flower-visiting insects that secure cross-pollination. Here are the scavengers that keep the earth clean—the sexton-beetles and the carrion-loving birds. But soil-making and seed-making are the two greatest benefits.

The fifth procession is that of man's enemies—a much smaller band than it used to be. Here are the beasts of prey with which primitive man struggled, learning many a valuable lesson in stratagem, patience, and courage. The poisonous snakes take a long time to pass, rowing on the ground with their ribs, and still biting man's heel. Crocodiles, alligators, and gavials levy their toll on the unwary, and sharks still follow the drifting wreckage or the divers who seek for pearls. Hercules seems to have practically finished off the octopus or hydra, though occurrences such as Victor Hugo describes in his *Toilers of the Sea* are still within the bounds of the possible.

Poisonous insects like hornets may still be formidable, and man must be careful lest he fall into the hands of the army-ants. But the insects that hinder man most are those whose bites serve for the injection of microbes, as in the case of the malaria-laden mosquito. This leads us to notice that in the course of ages the size of man's

enemies has dwindled greatly. Indeed, his worst enemies are in a sense those of his own household, the internal parasites like hookworm and bilharzia, or the minute predatory animals which cause malaria, syphilis, and sleeping sickness. But even these Lilliputian enemies are being conquered by man.

Pests

The sixth procession is made up of animals which injure man indirectly, by attacking useful animals and useful plants. Here are the pests that destroy man's animal stock or his crops. One thinks of the voles that sometimes eat up every green thing on the farm, or of the locusts that find a country a garden and leave it a desert. The procession is marked by a dense cloud of injurious insects, from cockchafers to cotton-weevils, from wheat-midges to warble-flies. Besides these there are worm-parasites in prodigious numbers, often doing serious damage among animals and plants alike. It is plain that inimical animals can do much more harm among herds or crops than in open Nature, for many victims are found within a short radius. The Colorado beetle was unimportant till man planted great fields of potatoes.

The seventh procession consists of animal enemies which injure man neither directly, nor through his stock and crops, but by getting at his stores or permanent products. Thus the termites or white ants in warm countries often cause serious loss and inconvenience, for they devour everything wooden and everything that approaches the wooden, from the books in the library to the corks in the cellar. Everyone knows the havoc that is caused by rats and mice, which often spoil much more than they eat. Of great importance also are the weevils and other beetles that feed on stored corn, or the larvæ of the flour-moth that devour army biscuits.

On Man's Side

The eighth procession makes us more cheerful, for it is made up of those animals that keep a check on the three contingents in front of them. In other words, they are man's *indirect* friends. Thus the birds of prey keep down the voles; the hedgehogs keep down the slugs; the lapwings devour the wireworms and leather-jackets; the ichneumon-flies lay their eggs in the caterpillars; the spiders catch the scale-insects; the lady-birds levy toll on the green-flies; the water-wagtails are fond of the small water-snails that harbour the juvenile stages of the liver-fluke; and so on through a very long list.

There is no object in elaborating the point, which is just this, that the circle of man's life cuts many other circles. He is the hub of a complex wheel, but it is a wheel within wheels. He is part of a web of life which he continues to fashion, and the success of his weaving depends on his understanding.

XLIX

INCREASE OF KNOWLEDGE, INCREASE OF SORROW

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A CRITICISM is sometimes advanced, in regard to the progress of science, that it makes things worse, not better. Instead of making, as Bacon said, for "the glory of God and the relief of man's estate," science is accused of filling human life with new horrors. Increase of knowledge is increase of sorrow, they say. Science is always up to some new devilry!

Science and Invention

How are we to meet this reproach? Part of the answer must lie in distinguishing between scientific *discovery* and subsequent *invention*. The chief end of science is understanding, and there can never be too much understanding, though it may be abused. Science primarily means Light, and the more light the better, even if it be used for evil purposes as well as for good. Science in so far as it is *luminiferous* is beyond all criticism, except, of course, that it sometimes makes mistakes; but that cannot be said of science as *fructiferous*, to use Bacon's words again. The evil is not in the scientific discoveries in the strict sense, but in some of the inventions which man has sought out. Yet this is only part of the answer, for the distinction between discovery and invention is not hard and fast; and many great discoverers, like Lord Kelvin, have also been great inventors.

Everyone admits that modern chemistry has made the world much more intelligible than it was before the days of Lavoisier. Scores of puzzles have been solved, and man's understanding of the life of his own body has made great strides. It is difficult for us to realise that before the time of Lavoisier—who was beheaded during the French Revolution—no one understood what breathing meant. But chemistry has grown from more to more, and the chemist has become a creator. From simple elements, as everyone knows, he can build up complex carbon-compounds; he can make natural substances artificially, which may be great gain when these natural substances are very scarce or cannot be procured except at great cost. He can also make new things which the world never saw before.

Coal-tar Beauty

Now we are not prepared to say that the making of, let us say, aniline dyes out of coal-tar has added to the beauty of the world; our point is that the making of these dyes was a natural practical outcome of theoretical advances in chemical science which have illumined the world. Moreover, while it does not seem to us that the invention of modern explosives has added to the welfare of the nations, it is only fair to recognise that there are other inventions, say chloroform, which are on the same general line of chemical synthesis. Adrenalin is a potent substance, of very distinct use in medicine and surgery; it is made in small quantities by the suprarenal glands; there is obvious gain in the practical invention which now produces it artificially.

It is not science that should be blamed for devilish inventions; it is the heart of man that is desperately wicked. Strychnine is a very valuable medicine; those who discovered it are not to be blamed because it can be used as a deadly poison.

Human society is such a complex business, and the laws of its evolution are so inadequately known, that it is extremely difficult to foretell what may be the results of this or that application of science. Who can tell what will happen if one pulls a thread out of a woven fabric?—and a human society or a civilised state is a very intricate web of life.

Not Enough Science

What is wrong is not that we have too much science, but that we have not enough for the complexities of the situation. It is likely that a big change in human activities will have correlated effects that are deleterious. It is very easy-going to suppose that because a new development was bound to come, and is sound on the whole, it may not in some way justify the criticism that increase of knowledge may be increase of sorrow. Even when the new development means an increase in the supply of wholesome food, we must be careful to inquire into all the human cost of the process; and it is also legitimate to inquire whether an increase in the possibility of "more people" is necessarily an unmixed blessing to the human race. The world is rapidly becoming very full, and it is by no means certain, to put it mildly, that it is being filled with people of the right sort.

Real Progress

The problem is how to anticipate the criticism that more science often means more sorrow. And what we have suggested may be re-stated in a more concrete way. The late Sir William Ramsay once said that real progress consisted in more economical use of energy—a very characteristically *chemical* utterance. If a new departure is very wasteful of natural energies, it is at once condemned.

But a new development which made more of available energies than ever before would not necessarily be commended by a biological tribunal. The lower must be judged by the higher, and the question would have to be pressed whether what was physically commendable was likewise good for the health of the workers and the community.

Similarly in regard to some biological proposals, such as, let us say, giving incurables a euthanasia, or sterilising undesirables, they may be excellent—we do not say that they are—from the purely biological point of view, but that is not the last word. Man is more than an animal; he is a reasonable social person. And the question must be faced whether these eliminative proposals, supposed for the sake of argument to be biologically sound, are also sound psychologically and socially. Do they do no violence to the spirit of man? Is social sentiment ready for them?

L

THE BEAUTY OF ANIMAL LIFE

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WHAT happens in us when we enjoy a beautiful animal like a peacock or an antlered stag or a scallop shell? There is a physiologically pleasant activity in our eyes and nervous system, and to this there is linked a joy. Through the nervous system—especially the sympathetic nervous system—the pleasant excitement overflows into outs and ins of the body. It seems to influence the beating of the heart, the breathing movements and other activities, either directly or through the regulative system of such ductless glands as the suprarenal body. For Wordsworth was a better physiologist than he knew when he said: "My heart leaps up when I behold a rainbow in the sky," or again, "And so my heart with pleasure fills and dances with the daffodils." To some people an ugly creature, deformed by man, is an actual source of pain, just like a discordant noise.

The Sensory Thrill

In some cases, as when we lazily watch the wind making waves on the hayfield, or the river flowing past, we may not get beyond the sensory thrill. What we see excites in us pleasant sensations, which may be enjoyed without much accompaniment in the way of joyous feeling. But in the great majority of cases we advance to a higher level of æsthetic appreciation.

We watch the gulls gliding against the wind, after a succession of powerful strokes, and the idea of fitness or adaptation flashes through our mind. We do not dwell on it, that would be science; but we cannot shut out its influence. We see the kingfisher dart up the stream, like an arrow made of a piece of rainbow, and we suddenly remember when we saw it last. We do not dwell on the memory, that would be reminiscence; but we cannot shut out its influence, and it probably adds to our joy. At another time there is an association of ideas. The swallows suggest migration and the circumvention of the seasons. The V-shaped phalanx of wild geese flying north suggests the misty islands and a waste of seas. In short, the æsthetic thrill is strengthened by ideas.

The Imaginative Touch

But there is a third level to which we rise occasionally, when we are influenced by sympathetic fancy. We project ourselves into what we see and enjoy its qualities vicariously. The soaring lark is an emblem of freedom. The salmon rising clean out of the water at the falls is significant of the insurgence of life. The spider's web is not only beautiful in itself; it gives us a responsive thrill that another living creature has attained to such a masterly use of materials. Life answers proudly to life.

The imaginative touch brings us to the confines of poetic fancy. Thus William Blake wrote:—

> And before my way a frowning thistle implores my stay,
> What to others a trifle appears
> Fills me full of smiles or tears;
> For double the vision my eyes do see,
> And a double vision is always with me.
> With my inward eye, 'tis an old man grey,
> With my outward, a thistle across my way.

In What is Beauty Expressed?

The qualities in animals that impress us as beautiful may relate to form, colour, and movement. There are forms that sing and lines that flow. Experiments with children show that preferences exist in favour of certain shapes, such as an ellipse with its axes in the proportions of 5:3. The eye is not fond of complicated shapes that are conundrums. We like lines that conspire to one effect. We enjoy the regular increment of the logarithmic spiral —an expression of orderly growth—which crops up so frequently in organic nature. We see it in spiral shells, in fir-cones, in the arrangements of young leaves in a bud, in the twisted horns of the antelope, and in many other expressions. Our theory is that the objective basis of form-beauty is in the rhythmic orderliness of normal growth. An unhealthy monstrosity, which would not be tolerated in wild nature, is bound to be ugly.

Daring Experiments in Coloration

In humming-birds, parrots, and birds of paradise, in butterflies, spiders, and coral-fishes, we find the most daring experiments in coloration. But they never seem to be wrong. These colours are often due to pigments—the waste-products or by-products of wholesome and unified living. Or, as in many shells that have no pigment at all, they are due to the regular occurrence of fine lines or fine plates which produce iridescent colours. And we may think of the regular occurrence of fine lines and laminæ as the ripple-marks of internal tides of rhythmic growth. In many cases pigmentary and structural colours are combined, as in peacocks' feathers. There are some luridly coloured skin-diseases, but they are always discordant. The exception proves the rule; they bear the stigma of their intrinsic disorderliness. Beauty is the hall-mark of the healthy.

Melody of Motion

When we watch jellyfishes throbbing in the tide, or a line of porpoises simulating a great sea-serpent, or the butterflies fluttering over the meadow, or a troop of cuttle-fishes keeping time with one another in the water, or the mayflies rising and falling in their evening dance, or the flying-fishes volplaning before the steamer, or the aërial evolutions of lapwings, we enjoy a sort of melody of motion; and this is a third factor in the beauty of animal life. The climax is when an animal, beautiful in form and colouring, is also beautiful in its eurhythmic movements.

Æsthetic Sense

In a few cases, such as bower-birds, there is obvious pleasure in brightly coloured objects. To decorate their honeymoon bower, these birds collect silvery leaves, gorgeous pods, beautiful shells, and the like; and there seems no reason to deny them an æsthetic sense. Then there are many cases where the male animals at the courting season show off their decorativeness, and it may be that their desired mates are not indifferent to the beauty-factor in the attractive *tout ensemble* of the rival suitors. Thirdly, it is difficult to believe that creatures that often fashion masterpieces, such as many nests are, have not some measure of the artist's joy.

When all this is allowed for—and we doubt if anyone has yet allowed for it enough—the question rises why animals are so beautiful in detail, and often very remarkably beautiful in their internal and quite hidden architecture. George Meredith has given us most of the answer in the simple words: "The ugly is only half-way to a thing." In Wild Nature we have to do with finished workmanship, with structures that have stood the test of time, with unified organisms from which there has been

gradually sifted out all that was in any degree discordant or contradictory. A living creature leading an independent life is a *viable* unity; and this is, we believe, the deep reason why it is also an *artistic* unity. Some animals are more integrated than others, with more unified and harmonious constitutions than others, and thus there will be different degrees of beauty.

We adhere to the thesis that all wild animals, fully formed, living an independent life, and not tampered with by man, have this quality of beauty which excites in us the æsthetic emotion. For we have not been able to get beyond the familiar definition of the beautiful: "A thing of beauty is a joy for ever." Exceptions must be made for some domesticated animals, which have become ugly under man's ægis, for some half-finished or embryonic stages (which are usually hidden away), and for thoroughgoing internal parasites that live a drifting life of ease. But these exceptions seem to us to strengthen our thesis—that all free-living, fully-formed wild creatures have the quality of beauty. The æsthetic emotion is our affair, it is subjective; we enhance it with thoughts and fancies, and these are obviously human.

No doubt there is easy beauty and difficult beauty. It is easy to attain to some degree of admiration for a peacock's tail; it is perhaps less easy to see the beauty of a grotesque like a puffin. Just as with pictures, some discipline is needed. Many people are quite honest in denying beauty to the hippopotamus, but they have not seen it with the eyes of the author of the Book of Job:

> Great behemoth, see him with his ruddy hide, in the shade of the lotuses, in the covert of the reeds and fens. His strength is in his loins; his force is in the sinews of his belly; the muscles of his thighs are knit together. His bones are pipes of brass; his limbs are like bars of iron; he is the chief of the ways of God.

We cannot see much of the beauty of an animal against which we have a strong prejudice, as against a snake or a stinging jellyfish. We must not expect every animal to be conventionally handsome; the point is whether it is an artistic unity. Thus a chameleon or a sea-horse is a grotesque, but no artist would for a moment think of either as ugly. Such libellous names as *Moloch horridus* indicate a careless acceptance of entirely conventional prejudice. On the other hand, we must welcome a change that has set in of recent years—the recognition of the beauty of very common creatures which crowd about our doors. We are learning the lesson of St. Peter's house-top vision.

LI

NATURAL HISTORY AND MEDICINE

NATURAL HISTORY AND MEDICINE

WHEN doctors dealt with animal simples and plant simples they had to be naturalists, and another ancient link was the leech, whose name became mixed up with the physician's. Most of the old animal prescriptions seem to be quite superstitious: the dust of a dried magpie was prescribed for epilepsy and the rheumatic patient was told to take a black cat to bed with him, because it is rich in curative electricity. But some of the old animal prescriptions have a smack of reasonableness. Thus, decoctions of ants, abounding in formic acid, might have antiseptic value; getting badly stung with bees might be of some use in rheumatism; and a diet of snails, with their copious digestive ferments, might have some virtue. Since the time of Aristotle dried toad and ashes of toad have been used in medicine, and we now know that the alkaloid poison called phrynin which exudes on the toad's skin has, when injected, a rapid effect on the contraction of the arterioles, the blood pressure, and the beat of the heart. In such cases the old prescriptions seem to be on a plane quite different from that of the type represented by eating a lizard to cure leprosy.

Treatment of Snake-bite

In regard to snake-bite, some of the old prescriptions are very interesting. Thus the natives of some countries

have been in the habit of drinking diluted snake poison to make themselves immune—and this is not very far away from the modern method of counteracting the poison by means of an anti-toxin serum prepared from a snake-bitten animal. In other native remedies the bile of the snake bulks largely, and it has been proved of recent years that the adder, for instance, actually carries about in the bile of its gall-bladder an antidote to its own poison. Something chemically near the cholesterin of the bile is found in the roots of certain plants, and we find snake-bitten natives chewing these roots! So it is not wise to smile too loudly at all the old-fashioned animal prescriptions.

Of course we must smile at the old advice given to the coward that he should eat the raw heart of a lion, or to the lethargic that he should dine on the brains of a ram, or to the jaundiced that he should try the liver of a fox. And yet are these not like adumbrations of the modern treatment of patients with defective or disturbed thyroid gland activity? For to them there is administered in some form or other the thyroid of sheep or calf.

Protozoology

The twentieth century has seen the establishment of many links between Natural History and Medicine, and it is interesting to bring a few of them together. Thus there has developed in a surprisingly short time a vigorous science of Protozoology which has on its medical side to do with the disease-causing rôle of many of the simplest animals or Protozoa. This new science has its laboratories, professors, and journals; it is becoming as important as Bacteriology. It is enough to mention three diseases which Protozoa cause—malaria, sleeping sickness, and syphilis. Talking of microbes leads us also to note that Metchnikoff's doctrine of phagocytosis—the rôle of

amœboid blood-corpuscles in engulfing and digesting virulent intruders—was to begin with a zoological investigation.

Medical Entomology

Closely associated with the development of Protozoology has been the advance of medical entomology. For there has been great insight into the part played by insects (and some of their distant relatives like ticks) in fostering and distributing disease-organisms. Long ago the peasants said: "Many mosquitoes, much malaria" and now we know how true this is. The mosquito is the nurse of the malaria organism and there is no malaria in man except through mosquito-bites. To suffocate the larval mosquitoes in the pools a little petrol or paraffin is poured on, forming a surface film to which the young insect cannot adhere with its respiratory tube; and here we see that the effective method of checking malaria by drowning the mosquito-larvæ depends on a little zoological knowledge of the respiration of aquatic insects.

Parasitology

The same point may be illustrated in regard to the Guinea Worm. This thread-like worm was probably the "Fiery Serpent" that troubled the Children of Israel when journeying in the desert. The female may be one to six feet in length; the male has been rarely seen. The juvenile stages are passed inside a small water-flea which is swallowed in unfiltered water. The adult female parasite tends to take up its position underneath man's skin, where it twists into a coil, and often forms an abscess or an ugly sore. Till recently the usual procedure was to coax out a small piece of the worm, which is like thin twine, and twist it round a strip of wood. Gradually and carefully the whole worm was uncoiled, but it took time. Nowadays

the patient sits with his feet or arm in water for hours on end, and the worm comes out of herself. Now this improved method depends on a zoological understanding of what the female worm is seeking in coming near the surface of man's body. She is trying to emerge into the water where the next generation begins.

One of the formidable worms of warm countries, such as Egypt, is Bilharzia, a peculiar kind of fluke, two species of which frequent the alimentary canal or the kidney region of man. They cause great pain because the sharp edges of the microscopic eggs cut into the walls of the blood-vessels and the like when the patient moves. In the early years of the war, Dr. Leiper discovered the life-history of this formidable and common parasite, showing that the juvenile stages are passed inside certain fresh-water snails and that they enter man (or some other host) through lesions in the skin. We understand at once why Bilharzia should be particularly common in children, for they are fond of wading in the water; and in washerwomen and those who water the gardens; and why our soldiers should have been infected after bathing. To remove obscurities is the first aim of science, but Dr. Leiper did more. He showed how the disease could be checked. Thus the microscopic larvæ cannot live for more than thirty-six hours in drawn water that is kept quite still; and they are baulked by thoroughly good filters. This is one of the finest instances of zoology helping medicine.

It is probably safe to say that one of the four biggest and heaviest clouds that have darkened the sky for man is that due to hookworm, a name given to several kinds of intestinal threadworms. They cause anæmia, weakness, lethargy, and despair—the "tropical depression" often deplored by missionaries, explorers, and colonists. But the zoologist has shown how the eggs pass from man to the soil and develop there into larvæ which enter man through the skin; and the hookworm campaign waged in

many parts of the world by the Rockefeller Institute has shown that if we could only persuade the natives that simple sanitation is life-saving, the cloud would entirely lift.

Vital Linkages

In great measure what is happening is that medical science is gripping the central zoological idea of vital linkages in the web of life. How are mosquito-larvæ to be killed off in Indian tanks for drinking-water, where the paraffin method is obviously impossible? By introducing little fishes called "millions" which devour the larvæ and do no harm. "Ye gods and little fishes!" Where there are many cats there are fewer rats, and therefore less chance of man being bitten by a rat-flea with its mouth-parts fouled with the bacillus of the bubonic plague, which is at home in the rat. Professor Patrick Geddes suggests that if there were a dovecot in the yard of the mill, where the workers have their mid-day meal, the pigeons would pick up the crumbs, which always attract rats, there would be less chance of bites from the rat-flea, and the dread journey of the bacillus of the plague (the old "black death") would perhaps never begin.

There are many links between zoology and medicine which are not less important than those we have mentioned. Thus the new lore of unit characters and their Mendelian inheritance is changing the attitude of medical science to the heredity of disease, and there is quite extraordinary suggestiveness in the zoological facts bearing on the influence of nurture (alimentary, functional, and environmental) on the development and growth of the individual.

Links Still to be Welded

But great as have been the services of zoology to medicine, the probability is that there are greater yet to come.

Can one read Professor Hodge's story of the worker-bee's brain without feeling that there is in it something big for medicine? The busy bee improves the shining hour, but the shining hour does not improve the busy bee! Its brain-cells go steadily out of gear, and the summer bee has a very short life. Careful microscopical examination shows that there is in animals (1) nerve-tiredness to which rest and sleep bring recuperation; that there is (2) nerve-fag from which recovery is possible but difficult; and that there is (3) nerve-fatigue which means a fatal cell-collapse. And that is what the worker-bee dies of.

Then there is Dr. Werber's contribution to the problem of the origin of monstrosities. A little butyric acid induces extraordinary monstrosities in the head-end of American top-minnows. It dislocates and in part disturbs the germinal material of the head. But what respectable embryo could ever be influenced by butyric acid? The answer is that when something goes wrong with the chemical routine dealing with carbohydrate food, there may be a formation of butyric acid as a by-product. And butyric acid in the blood of the mammalian mother might seep through to the young embryo in the womb and induce monstrosities.

Or take this as a final illustration. It is well known that the eggs of many animals—from sea-urchin to frog—can be launched on the voyage of development without being fertilised. By using various stimuli and then restoring the excited egg to normal conditions, there comes about *artificial* parthenogenesis. It is also well known that a lost part—the arm of a starfish, or the leg of a crab, or the tail of a lizard—can be readily regrown. There is intense regenerative activity at the area of breakage. Then, again, it is a familiar fact that the salivary juice of a gall-fly's larva, developing in the tissue of a leaf or shoot, incites a wonderful gall-growth, such as an "oak-apple." Now let us suppose we could saturate ourselves in the facts along

these three lines of zoological investigation, and put our best brains into reflecting on the data, might we not perhaps get a gleam of light on the dark problem of cancer? The links between Natural History and Medicine require to be tightened, not slackened, multiplied not reduced. New contacts between sciences are always rewarding.

LII

THE NEW NATURAL HISTORY

THE NEW NATURAL HISTORY

In byegone days, in more than one Scottish University there was a Chair of "Civil and Natural History." These were the days when the professor took for his subject not only the domain of things but also the realm of organisms, and also without any embarrassment threw in the kingdom of man. But in the course of time it was found desirable to knock off Civil History— there were would-be professors desirous of chairs—and Natural History came to mean the study of the whole outer world, human affairs excepted. It was still a great field! Later on came the inevitable cleavage between the sciences—more or less exact—of chemistry and physics, and the sciences—less or more exact—of botany and zoology. Geology, with a finger in both pies, kept close for many years to Zoology, and it was not till 1899 in the University of Aberdeen, for instance, that Natural History, shorn of much of its glory, became, for practical purposes, Zoology; for Botany had long previously separated itself off, thanks partly to the ægis of Medicine, which, having disowned "animal simples," clung the more tenaciously to pharmaceutical plants. Thus Natural History came to be a synonym for Zoology, as apart from Botany, and still more apart from Geology. This remains the most frequent usage; and it should die, for it is useless.

Meaning of Natural History

There is something very fine in the old idea of "Natural History"—that there is but one great subject of concrete

study—the Order of Nature. But we cannot revive the term "Natural History" along that line; it is more practical to lay emphasis on the correlation of the sciences, which Principal Caird saw so clearly from the synoptic, philosophical side. While we may be justifiably reserved in regard to the unity of science, for that implies an orchestration of concepts that has not yet been attained, we are all agreed as to the unity of aim, which is the understanding and, if possible, mastery of what goes on in Nature.

But there is much to be said for retaining the old-fashioned term Natural History as a label for the study of habits and surroundings, as a synonym for what is often called ecology or bionomics. There is certainly need for a name for what a great zoologist used to call "the higher physiology," the physiology of organisms as contrasted with the physiology of organs. Natural History is the study of living creatures as intact unities in their natural environment. It is the study of the everyday life of caring for self and caring for others. It is the study of habits and inter-relations; and Zoology and Botany apart from Natural History lose no small part of their charm and significance.

Changes in Natural History

It is a familiar fact that the aspect of a science sometimes changes in a single generation, and the question we wish to ask is how Natural History has been changing since pre-Darwinian days. How does the Natural History of Mr. Beebe differ from that of Gilbert White? Many of us have become painfully aware of the changes in, say, Chemistry and Physiology, since we began to study them: there has also been a great change in Natural History, and it is interesting to analyse this. A change in a science may be due to new facts, such as radio-activity; or to new

ideas, such as evolution and the transformation of energy; or to new contacts, as when psychology joined hands with physiology; or to new methods, such as those involved, for instance, in microscope and spectroscope. All these kinds of influences have played upon Natural History, and there has been a process of ripening. Childish things have been put aside and Natural History has gained in seriousness of purpose and in dignity.

The Web of Life

One of the most marked changes is that the idea of the correlation of organisms in the web of life has become the centre of Natural History. This is largely due to Darwin. Nothing lives or dies to itself. Everything, as John Locke said, is a retainer to some other part of Nature. The earthworms plough the fields; the bees and the flowers are hand and glove; the mistle-thrush plants the mistletoe; the minnow nurses the mussel; the water wagtail helps the sheep-farmer; and the squirrel has its share in making the harvest a success. Suppose the glory that was Greece was in part dimmed by the obtrusion of malaria, as some historians say; the disease is sown by mosquitoes; the aquatic larval stages are very effectively checked by minnows. Once more, "ye gods and little fishes!"

Precise Study of Behaviour

Another change of a welcome kind is evident in regard to the whole study of animal behaviour. In old days the interpretation that was put on a piece of animal behaviour was very largely dependent on the observer's temperament. If he was generous and what William James called "tender-minded," he read the man into the beast without hindrance. Every mammal was a Brer Rabbit and a honey bee a mathematical genius. But if the observer

was parsimonious and accustomed to use William of Occam's razor, being what James called "tough-minded," he set his face sternly against all anthropomorphism and reduced the animal to the level of an automatic machine. In shunning the Scylla of anthropomorphism, the observer fell into the Charybdis of a psychic behaviourism, or vice versa. Now we have become more precise and critical, thanks largely to the work of Lloyd Morgan and Jacques Loeb, working from different ends. There is a recognition of a long series of kinds of activity, from reflex actions to rational conduct, arranged as branches from an ascending curve; and no act is ascribed to a higher mental faculty if it can be satisfactorily described in terms of a lower. Comparative psychology has emerged. The word instinct is no longer used by the naturalist in six senses.

Evolutionism

Another set of changes is due to the evolution theory. The affairs of life are seen in a historical setting. Everything is an antiquity. Thus the naturalist looks back to the three great invasions of the dry land by aquatic animals, and traces in present-day habits the adjustments made by the conquerors of the new kingdom. The old method of simply liberating the eggs into the soft cradle of the water had to be departed from. Eggs on the surface of the ground would be dried up and devoured. So we bind together in a reasonable way all the arrangements by which terrestrial animals secure the safety of their eggs and young—nests on the trees, shafts sunk in the ground, silken bags that are hidden away or carried about, external brood pockets and internal viviparity, a return to the water for this particular period, and the utilisation of another animal as a cradle. These are only instances out of a long list of devices, which are unified by their historical or evolutionary setting.

Adaptations

The old naturalists were interested, as we are, in the adaptations of living creatures to the peculiar conditions of their existence, but they generally regarded these fitnesses as endowments conferred, whereas we think of them as the long results of time, some of them still imperfect, some of them almost startling in their finish. There is a small Hymenopterous insect that lays its eggs in the larvæ of gall-midges found in the wood-vessels of freshly cut trees. From the dorsal surface of its posterior body a remarkable hollow horn arises which extends forward over the thorax and ends just over the anterior eye-spot on the head. What an extraordinary structure! But its adaptive significance is clear. For it is confined to the females and it turns out to be a sheath for the protection of the extraordinarily elongated ovipositor which is able to reach down to the midge larvæ deeply ensconced in the vessels of the tree. The old Bridgewaterism was content to admire; the new Natural History tears its hair in the search for genetic description.

Subtlety of Animate Nature

Some of the old naturalists, men like Réaumur, had a keen appreciation of the subtlety of animate nature, but perhaps their successors have penetrated further. "I scrutinise life," Fabre said; and what revelations he has given us of the *vie intime* of insects! His mantle has fallen on others. Mr. Beebe, travelling naturalist to the New York Zoological Society, is a good example. Recall, for instance, his vivid picture of the ways of the leaf-cutting ants, to which we have already referred. They climb trees, they cut off segments of leaf, they carry these to the underground nest, and make them into a green paste which is used as a culture-medium for a particular kind

of mould not found anywhere else. This mould forms the exclusive food of the leaf-cutters in their subterranean life.

There are other interesting features in the new Natural History, indicative of a growing ripeness and precision. There is more definite correlation of the organism with its particular haunt and with the cycle of the seasons. The picture is less luridly red in colour than it used to be, for it has become clear that an answer-back that counts for much in the struggle for existence is *caring for others.* There is a growing appreciation of the amount of time and energy that animals devote to ends that are rather species-regarding than self-preservative. It is plain that in ordinary physiology and anatomy, embryology and genetics, little account is taken of the individual as such. We study features that are common to the species or type. But it is otherwise with Natural Hsitory; we must study the behaviour of *the individual.* And when we begin to see the animals we study not only as structural and functional unities, with an individual development and racial evolution behind them, but as animal personalities at various levels, as creatures with mental aspects, as agents that endeavour after well-being and share in their own further evolution, as threads in a quivering web of life, we begin to know what is meant by the new Natural History.

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